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RADIOGRAPHIC INTERPRETATION GUIDE FOR ALUMINUM ALLOY WELDS

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16. Abstract

The problem of radiographic interpretation has plagued the X-ray method of nondestructive testing since its beginning. In an attempt to achieve a more accurate interpretation of radiographic images of aluminum alloy welds, a program designed to correlate specific images with corresponding discontinuities was initiated. Radiographs were made of welds that contained different types of discontinuities. Subsequent metallographic studies were made to confirm the image types and shapes as depicted in the radiographs. These experiments required very precise welding techniques to produce the various types of discontinuities found in typical aluminum welds. Exact radiographic techniques and careful metallographic methods were also necessary to achieve program objectives. Lack of agreement on terminology has also plagued the advancement of radiographic interpretation. Therefore, the radiographic terms used in this report have been carefully defined in order to eliminate as many interpretational errors as possible. The resultant data show clearly that radiographic interpretation can be placed on a scientific basis.

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TECHNICAL MEMORANDUM X-53939

RADIOGRAPHIC INTERPRETATION GUIDE FOR ALUMINUM ALLOY WELDS

SUMMARY

The problem of radiographic film interpretation has plagued this method of nondestructive testing since its beginning. This report is an attempt to establish a better understanding of the different types of discontinuity images' actual shape and type as they appear on the radiograph, compared with their metallographic appearance. It will also serve as an effort to standardize radiographic terminology so that confusion arising from individual description of radiograph images will be lessened. The examples used were picked because some of them are often misinterpreted. The data show clearly that the correct interpretation of radiographic images of aluminum alloy welds can and should be made with such a guide.

INTRODUCTION

The radiographs contained in this report are not intended to be a reference for any specification. This guide helps in identifying the different types of discontinuities found in aluminum alloy welds. It is for those who are now, or will be, engaged in the interpretation of radiographs of fabricated components of aluminum alloys.

This report is intended to familiarize personnel who are actively engaged in the interpretation of radiographs with the comparison of the radiographic image and the actual discontinuity type and shape as determined by metallographic study. Other purposes are to put radiographic film interpretation on a more scientific basis rather than depending upon individual interpretation and to standardize the radiographic terminology of the different types of discontinuities.

While optimum radiographic film sensitivity is discussed, this report is not intended to be a refined radiographic technique guide. It is selective in the sense that the only area concentrated upon is the radiographic interpretation of discontinuities found in aluminum alloy welds.

This report will also serve the stress engineers and the Materials Review Board personnel as a guide for more accurate evaluation of a particular type and shape of discontinuity.

INTERPRETATION OF RADIOGRAPHS

Theoretical explanations cannot be substituted for long practical experience in interpreting weld radiographs. Despite this limitation, some indications of the basic interpretation considerations are helpful, and the following should be emphasized initially. When reading weld radiographs, the film interpreter must be able to explain correctly all indications of the film. Indications arise from internal discontinuities in the test object, from surface discontinuities, external test conditions, and from careless film processing or damaged film holders. Errors in interpretation can be avoided only if the sources of various indications are identified correctly. While interpretation errors can lead to loss of time and money in efforts to repair imaginary defects, failure to point out existing defects can be more costly.

After assessing the possible indications arising from extraneous sources such as film, holders, and processing, the interpreter should not restrict himself to fixed schemes of discontinuity images in interpreting these images originating from the test object. Instead, he should have in mind the fundamental principles of the rays intercepted by the test specimen, the three-dimensional shape of the discontinuity, and the way it intercepts the rays to form the image. Useful indications are provided to this mental process by (1) the shape of the image, (2) the distribution of density in the image, and (3) the direction of the incident rays upon the test object and upon the film.

To fulfill his task, the interpreter should know the fundamental characteristics of radiation with respect to the test material. He should also know the fundamentals of the manufacturing process that produced the product he is radiographing. In the case of weldments he should know the different welding methods, their peculiarities, their possible and most probable defects. Wherever possible he should know in advance the specific welding method employed.

In other cases he should have similar information about castings, assemblies, and other articles.

Only under these conditions can the test method give the best results. Properly applied, radiography is not restricted to a mere "Go-No-Go" test for detecting voids or defects. Its function is enlarged to provide useful information to the production shop which can lead to possible improvements in manufacturing techniques.

Correct interpretation of radiographs is based upon the supposition that the entire technique employed in the production of the radiographs has been satisfactory. Many exposure factors are important and should be recorded to guide the interpreter properly. The mere presence of an adequate image quality indicator (penetrameter image) and a satisfactory film density does not guarantee that the radiograph is adequate. When a radiographer is called upon to interpret an image of a test object with which he is not familiar, it is highly desirable that a sample part be available or that a good photograph of it be provided. In addition, the interpreter should be familiar with the service conditions and stresses for which the part is intended. If possible he should have available adequate information concerning the influence of discontinuities and other material conditions upon serviceability. In evaluating the effect of the location of discontinuities upon serviceability, the designer's data on stress conditions, machining, or processing are valuable aids to the film interpreter.
preter.

Since every discontinuity shown on a radiograph is not necessarily rejectable, the word "defect" is not used until the interpreter makes a decision after comparison with the applicable specification.

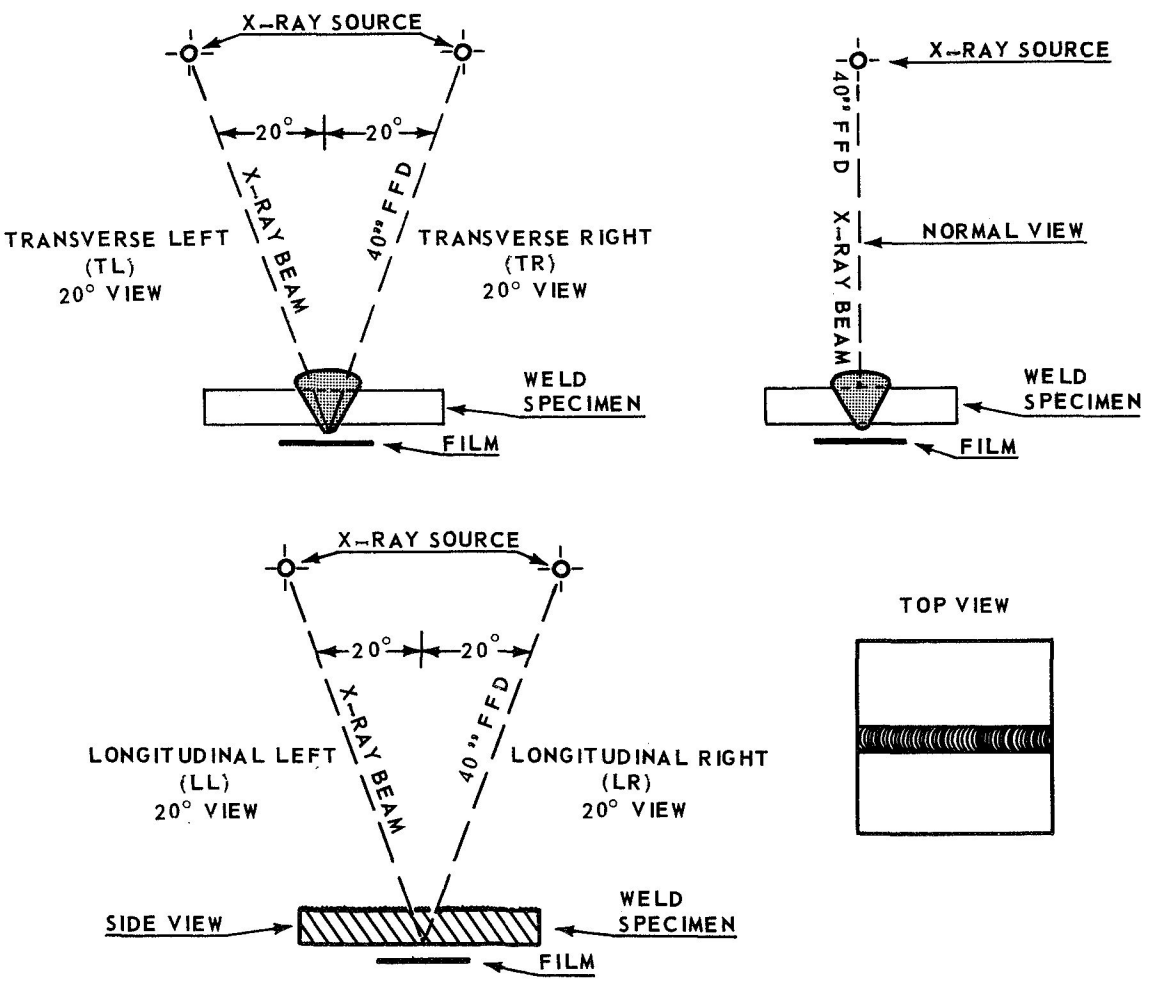
Radiographs should be examined with a film illuminator that provides a strong light source capable of penetrating film with high densities. The viewing surface should remain cool to avoid damage to the film. Light from the source should be diffused through a suitable medium. Film viewing should preferably be done in a suitable area that can be partially darkened and that provides desk space with writing area. Before starting work, the interpreter should remain in this area for periods of 2 to 10 minutes under reduced illumination levels, to permit eye adaptation.

DISCUSSION

The specimens used in this program were fabricated from the same types of aluminum alloys used in the first three stages of the Saturn V Vehicle, and the welds were made using the same procedures specified for flight vehicle welds [1]. More specifically, materials used were 2219-T87 with 2319 filler wire and 2014-T6 with 4043 filler wire.

Examples of discontinuities are shown in Figures 1 through 28. Photomacrographs are shown on Figures 1a through 28a and corresponding radiographs are shown in Figures 1b through 28b respectively.

This report contains five different radiographic views of each weld specimen. More specifically, one normal, two transverse, and two longitudinal views of each specimen were made as depicted in the following diagrams.



The pictures of the radiographs are mounted with the normal view in the top center position, and the transverse left and the longitudinal left views are mounted in the left side position. The transverse right and the longitudinal right views are mounted in the right side position. A description of the weld specimen and its thickness and an interpretation of the discontinuity found in the radiograph are given on the right-hand page of the book. The discontinuity of interest on the radiograph is indicated by the arrow. The other discontinuities were not considered because they bear no relationship to the actual discontinuity type and shape as determined by the metallographic study.

The photomacrographs are mounted on the left-hand page for a comparison with the radiographic image. These have the description and the magnification of the discontinuity in standard radiographic terminology, alleviating the confusion of evaluating the discontinuity in the radiograph. It is noted that the greater magnification is reversed from the less magnified photomacrograph because different types of metallographic equipment were used to make the photographs.

It must be emphasized that the specific purpose of this report is to aid personnel concerned with the identification of different types and shapes of discontinuities found in aluminum welds.

PROCEDURES

The X-ray equipment used for the radiography in this report was an MG-150 with a voltage range from 25 to 150 kV, and a current range of 0 to 15 ma. The fractional focal spot tube of 0.7 mm and 2.5 mm was used with the smaller focal spot. The focus to film distance (ffd) was a constant 40-in. The voltage was from 30 kV for the thinner material to 110 kV for the thicker material. The exposure time was a constant two minutes. The current was a constant 8 ma. The film was the very fine grain type, and it was processed in an automatic X-omat film processor.

The metallographic studies were done in three planes; transverse section, parallel section, and the surface plane section. Film sensitivity was 1.4 percent or better.

All the radiographic views are the actual size of the weld and the discontinuity. The sizes of the discontinuities range from 0.015 in. in the thinner materials to 0.150 in. in the thicker materials.

Some of the standard terminology used in this report can be found in Reference 2. The rest has been acquired by the authors during many years of experience with radiographic interpretation of aluminum alloy welds. The welding procedures used to prepare the specimens are found in Reference 1. Other specifications of concern are found in References 3 and 4.

The standard radiographic terminology used in this report is used throughout industry. A list of standard terms and some additional suggested terms to describe discontinuities are defined as follows:

artifact	A false indication. Appears as dark crescent marks, light marks, or chemical smudges on a radiograph.
burn through	Burning away of the parent metal in the root of the weld. Appears as a dark smooth void.
crack, crater	Crisscross or star cracking, on or just beneath the surface. Appears as a dark crisscross or star shape with ragged edge lines.
crack, longitudinal	A crack running parallel with the weld, sometimes in the parent metal. Appears as a dark ragged line.
crack, underbread	A subsurface crack in the parent metal, parallel with the weld. Appears as a dark ragged line.
discontinuity	Any interruption in the normal physical structure or configuration of a component, such as cracks, porosity, or inclusions. A discontinuity may or may not affect the usefulness of a component.
enigma	Still no satisfactory answer as to what this really is. Appears on the radiograph as a smooth dark line accompanied by a light line, very much like incomplete fusion, except that it appears in any part of the weld metal.
inclusion, less dense or inclusion, oxide	Usually aluminum oxides entrapped in the weld metal. Appears as dark irregular voids with ragged edges and sharp angles.
inclusion more dense	Normally tungsten or some other more dense material entrapped in the weld metal. Appears as light spots in the weld metal.

incomplete fusion	Failure of weld metal to fuse with parent metal or self. Appears as one or more dark wavy lines on either side of weld.
incomplete penetration	Failure to completely penetrate the parent metal. Appears as a dark straight line in the center of the weld.
porosity, clustered	Gas entrapped in the weld metal. Appears as a group of three or more smooth dark; small, medium, or large; round, or elongated voids.
porosity, connected	Gas entrapped in the weld metal. Appears as dark smooth round, or elongated voids, connected together.
porosity, isolated	Gas entrapped in the weld metal. Appears as a single dark smooth round, or elongated void separated by two diameters of itself to the nearest void.
porosity, linear	Gas entrapped in the weld metal. Appears as a series of two or more smooth dark, round, or elongated voids in a line.
porosity, tailed	Gas entrapped in the weld metal. Appears as a dark void with a sharp angle or small tail-like line leading from the void.
suckback	The under portion of the weld has the appearance of being sucked up into the weld. Appears as a dark broad line in the penetration zone of the weld.

CONCLUSION

Errors in the interpretation of discontinuities can lead to the loss of time and money in efforts to repair imaginary defects, but failure to point out existing defects can be more costly. These interpretation errors can be avoided only if the sources of various indications are correctly identified. For this reason the particular purpose of this report is to aid in identification of the different types of discontinuities found in aluminum alloy welds and to standardize the use of radiographic terminology for the fabricators of aluminum alloy components.

Oxide inclusion is the most often misinterpreted discontinuity, many times being interpreted as porosity. This does not give stress engineers and Material Review Board members a true interpretation of that particular discontinuity, and it could result in an unacceptable component being used, thus weakening the structure.

Another erroneous interpretation is that of an oxide inclusion with sharp angles which is often interpreted as porosity, again not giving cognizant personnel a true evaluation of the discontinuity. This type of discontinuity is more detrimental to a weld than smooth gas porosity. Still another erroneous interpretation is of tailed porosity. The average interpreter will not observe that this type of porosity has a line extending out of the void, so it is more often referred to as "porosity." The tail acts as a stress riser and is more detrimental in a weld than smooth gas porosity.

The enigma is the most difficult discontinuity to determine, often being mistaken for incomplete fusion, and many times for a crack, or even a diffraction pattern. Identification of an enigma demands long experience in interpreting radiographs. The interpreter should notice that the dark line is always accompanied by a parallel light line. Many destructive tests for strength have been made of this type of discontinuity, but so far there has been no noticeable effect on the weld's ultimate strength.

This report should serve as a guide in the interpretation of radiographs to help clarify the different types of discontinuities found in aluminum alloy welds and to help standardize the terminology used for the interpretation of radiographs. This would lessen the confusion arising from each individual using a different terminology, and it would put radiographic interpretation on a more scientific, rather than an increasingly individual basis.

REFERENCES

1. MSFC-SPEC-135: Specification for Fusion Welding of Aluminum Alloys.

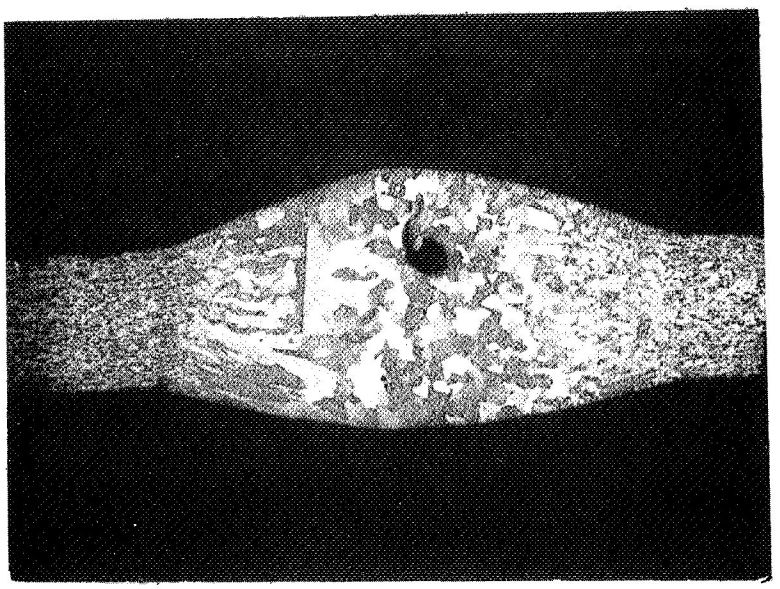
2. McMasters, R. C.: Nondestructive Testing Handbook. Section 25. Interpretation of Radiographs.

3. MSFC-SPEC-250: Radiographic Inspection. Soundness Requirements for Fusion Welds in Aluminum and Magnesium Missile Components.

4. MSFC-STD-397: Radiographic Laboratory Certification.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



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TAILED POROSITY

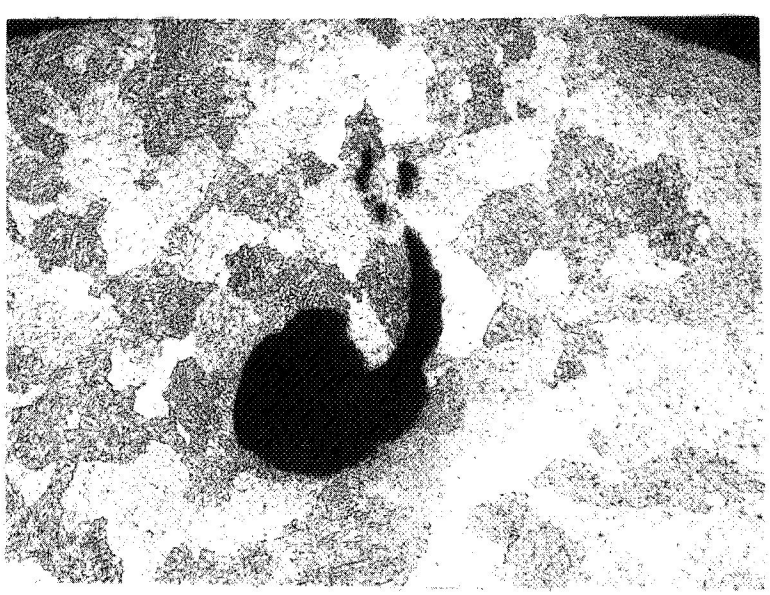

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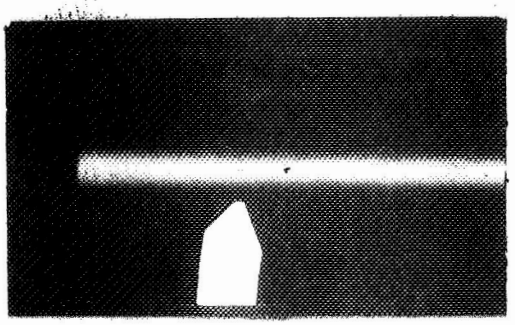
Figure 1a.

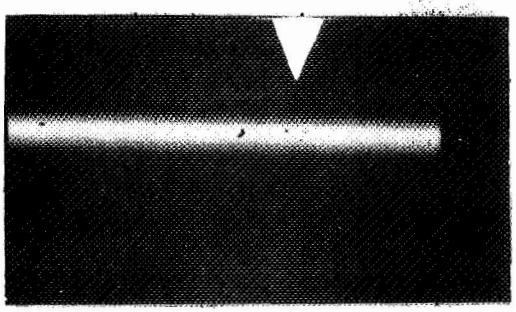
RADIOGRAPHS OF ALUMINUM WELDS

MAT. 2219
THICK. 0.063"

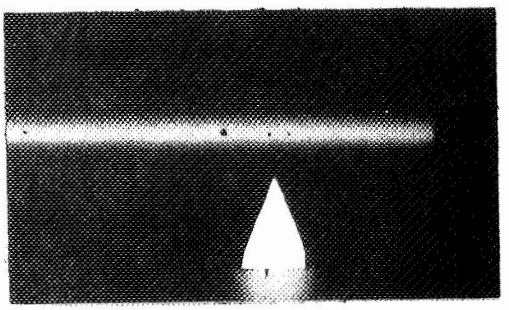


TAILED POROSITY

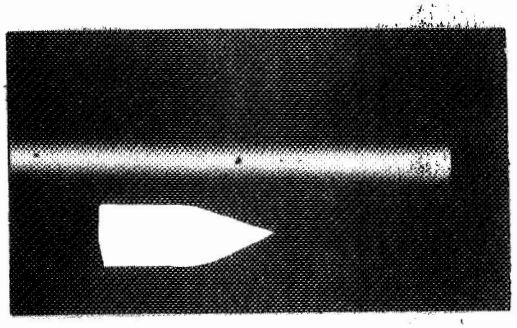
90°



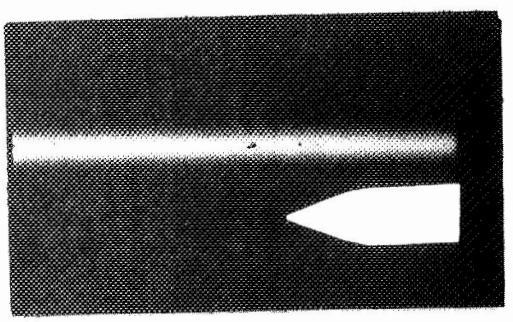
20°TL



20°TR



20°LL

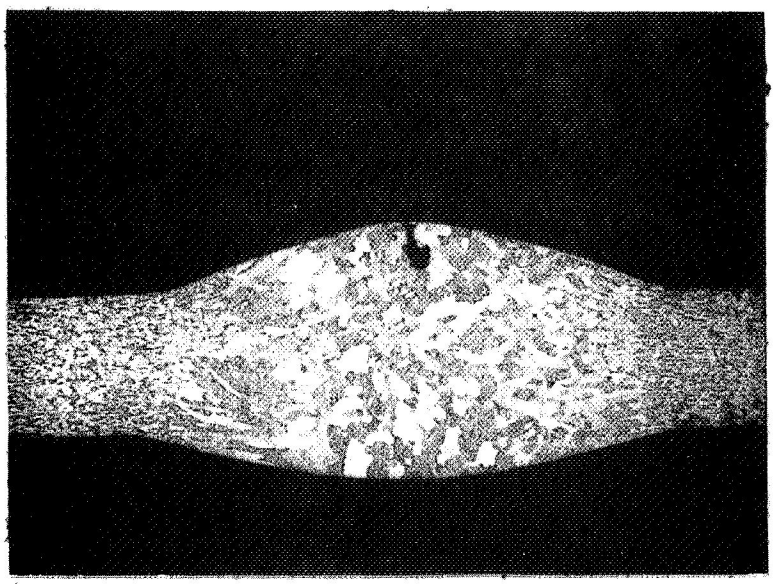


20°LR

Figure 1b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



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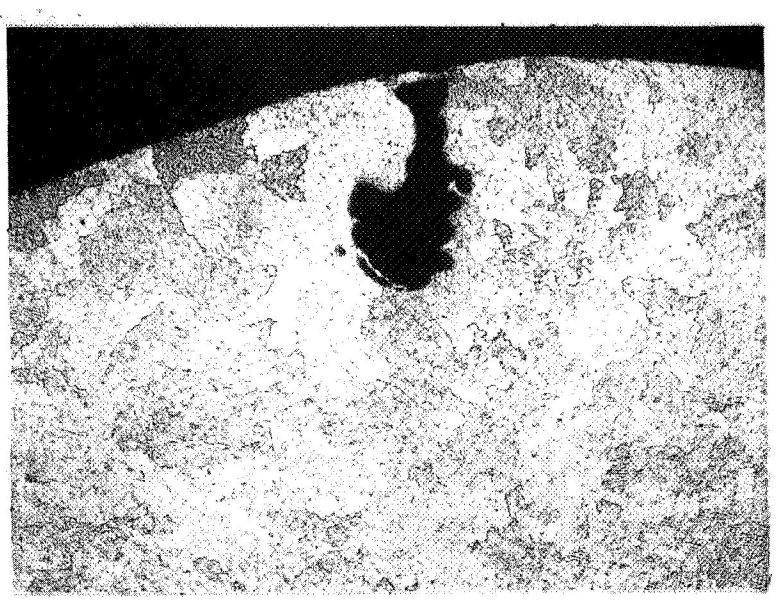

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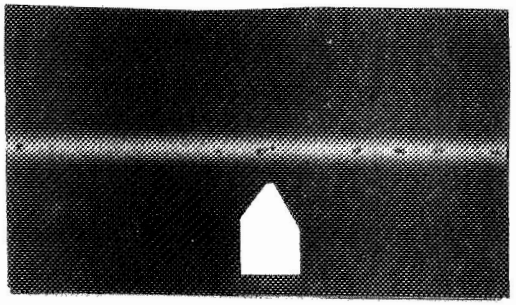
Figure 2a.

RADIOGRAPHS OF ALUMINUM WELDS

MAT. 2219
THICK. 0.063"



CONNECTED POROSITY

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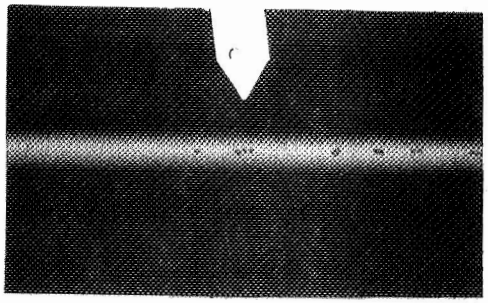
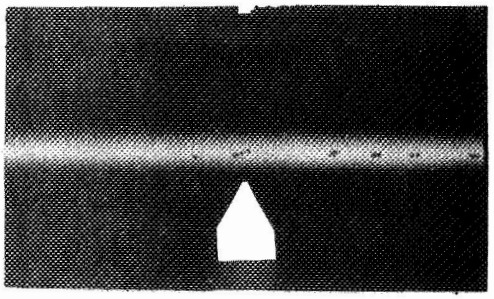


20°TL



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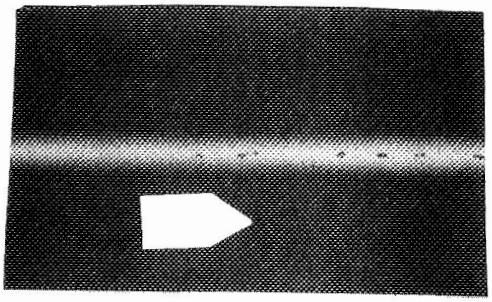

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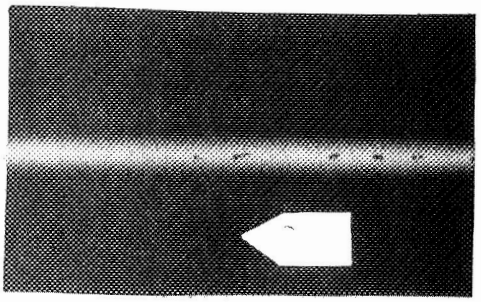
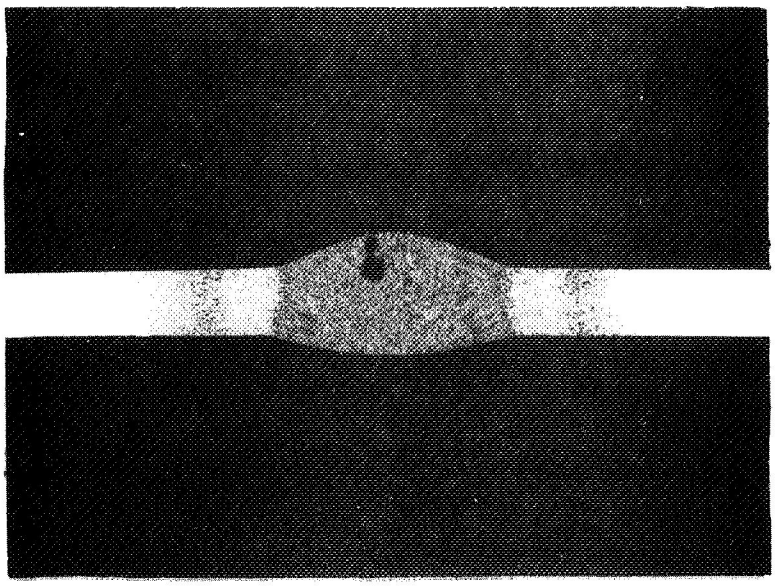


20°LR

Figure 2b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



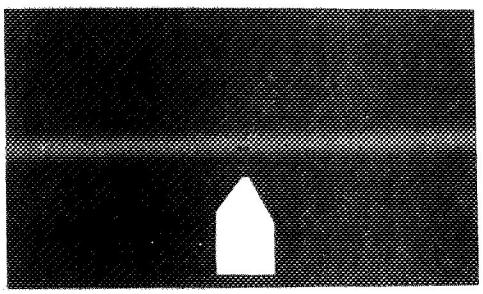
10 X MAG.
CONNECTED POROSITY

50 X MAG.

Figure 3a.

RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 0.063"



TAILED POROSITY

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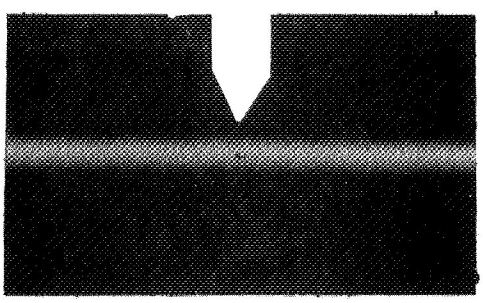

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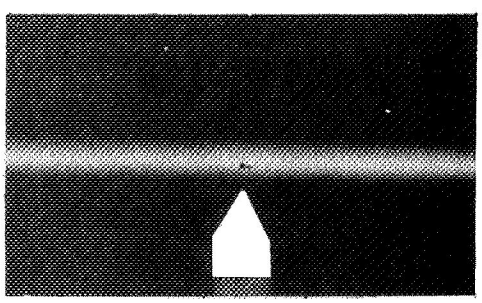

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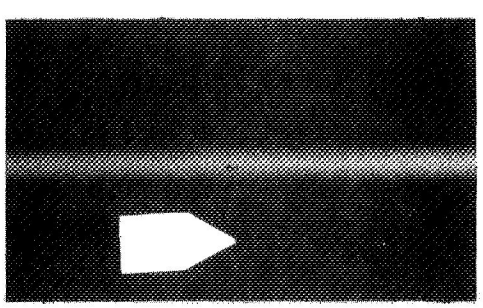

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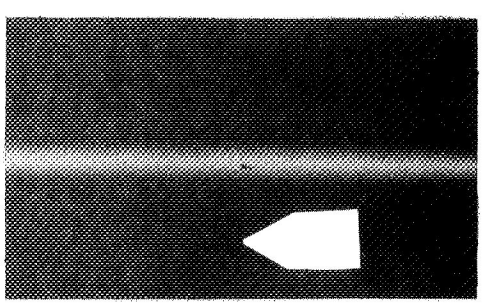
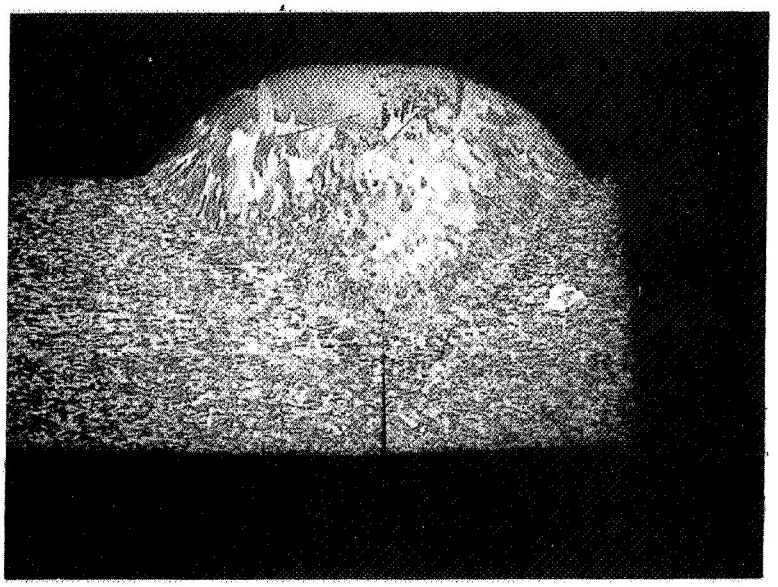


20°LR

Figure 3b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



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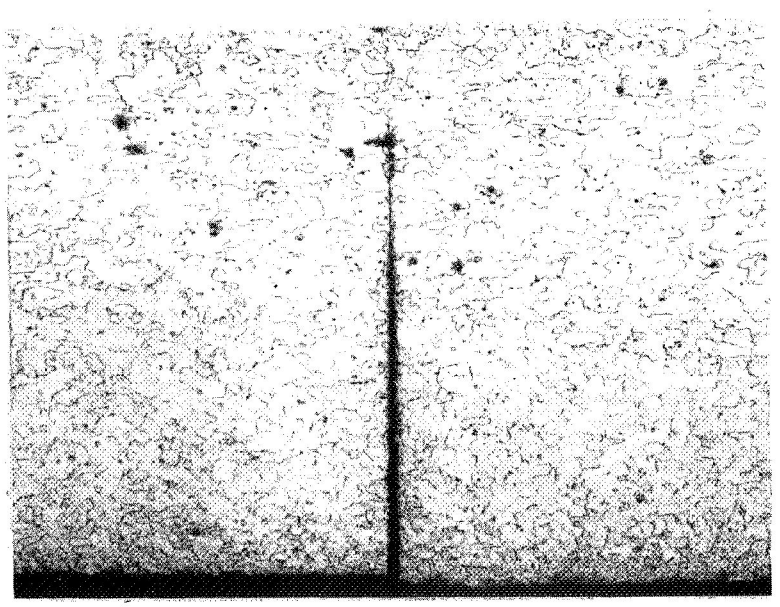
INCOMPLETE PENETRATION

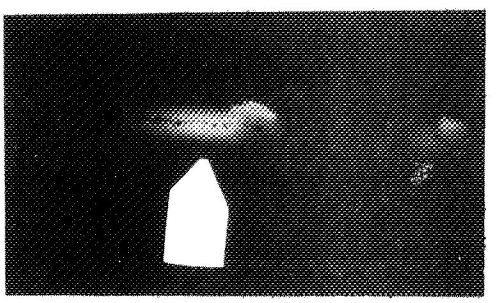


50 X MAG.

Figure 4a.

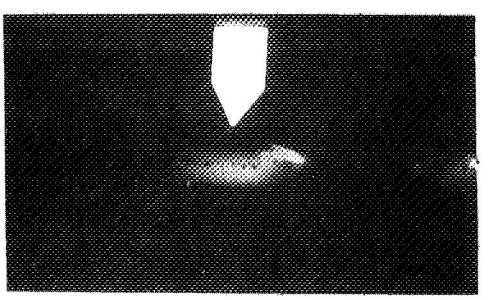
RADIOGRAPHS OF ALUMINUM WELDS

MAT. 2219
THICK. 0.125"

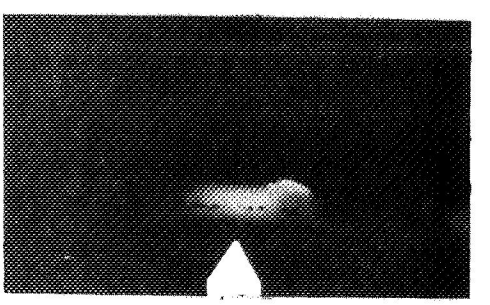


INCOMPLETE PENETRATION

90°



20° TL



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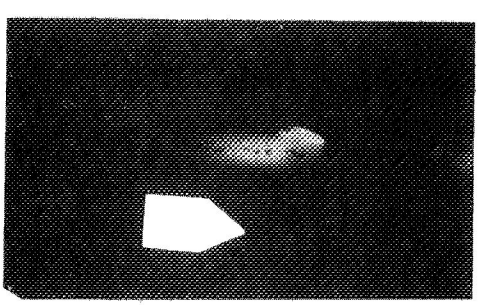
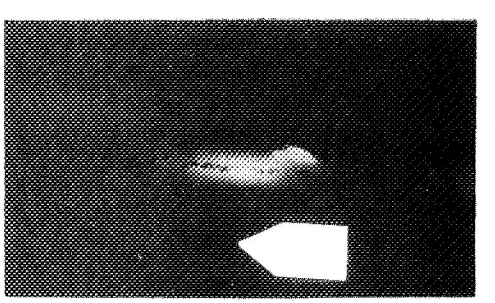


20° LL

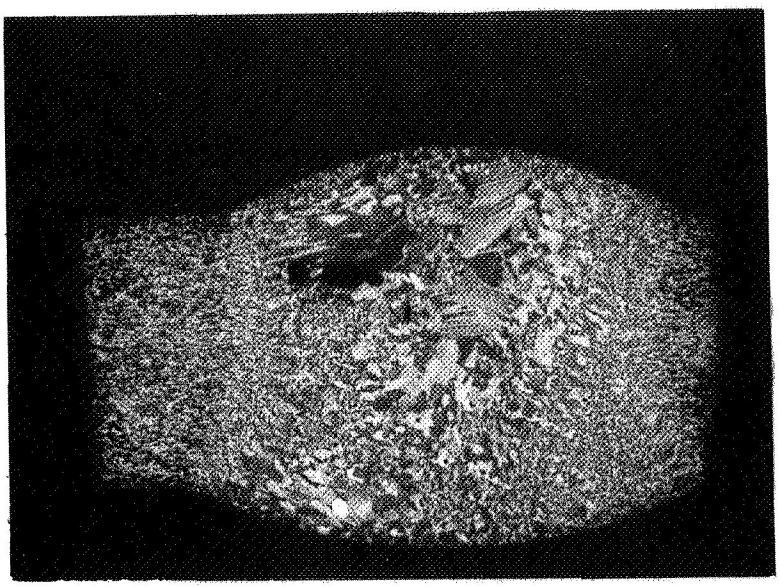


20° LR

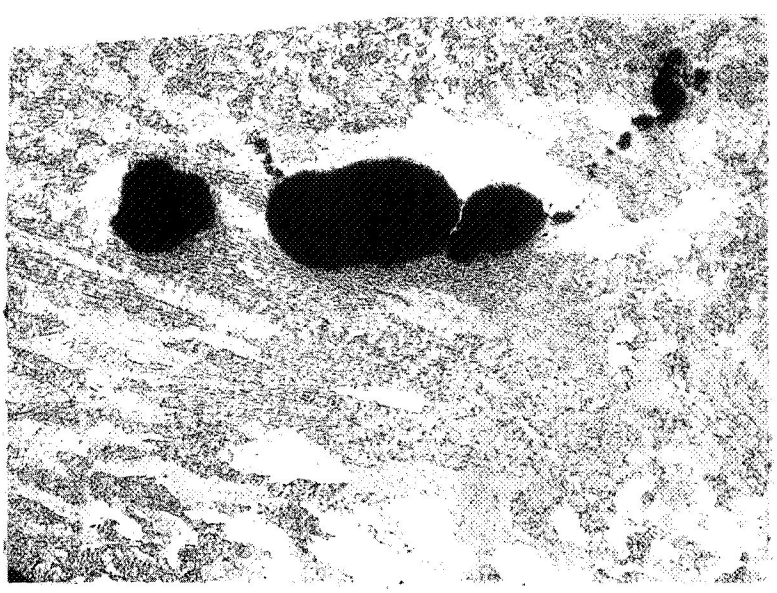
Figure 4b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



10 X MAG.
CLUSTERED POROSITY

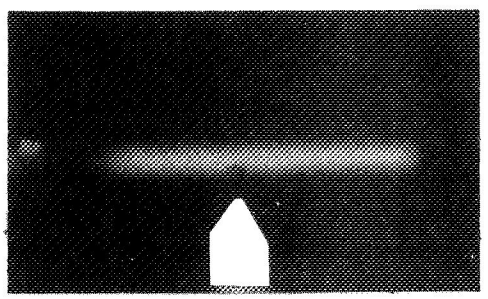


50 X MAG.

Figure 5a.

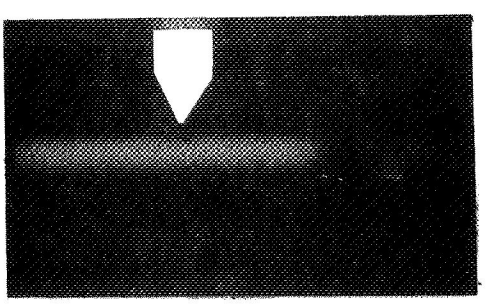
RADIOGRAPHS OF ALUMINUM WELDS

MAT. 2219
THICK. 0.125"

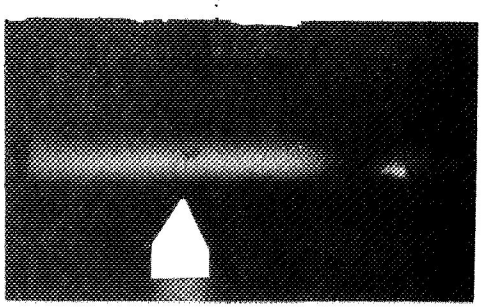


CLUSTERED POROSITY

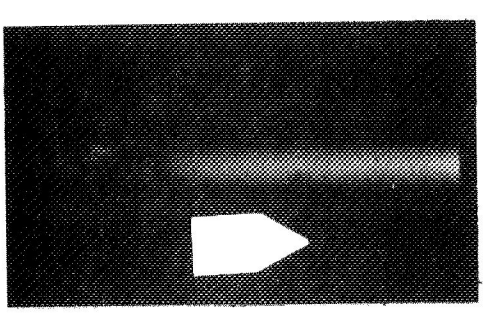
90°



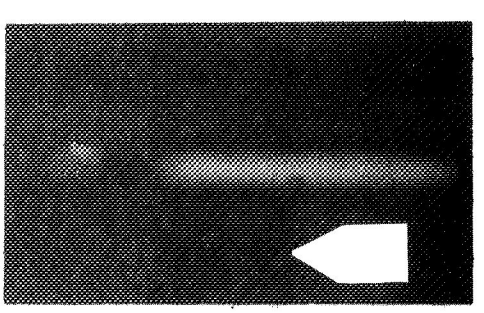
20°TL



20°TR



20°LL

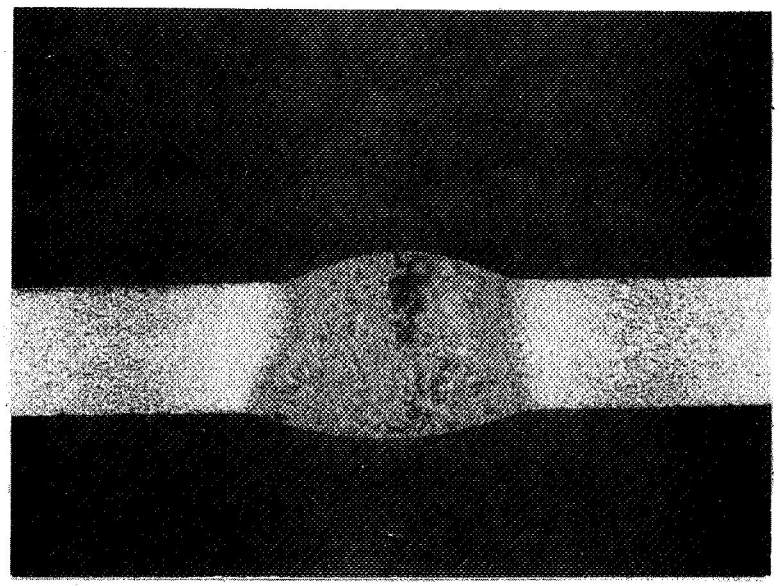


20°LR

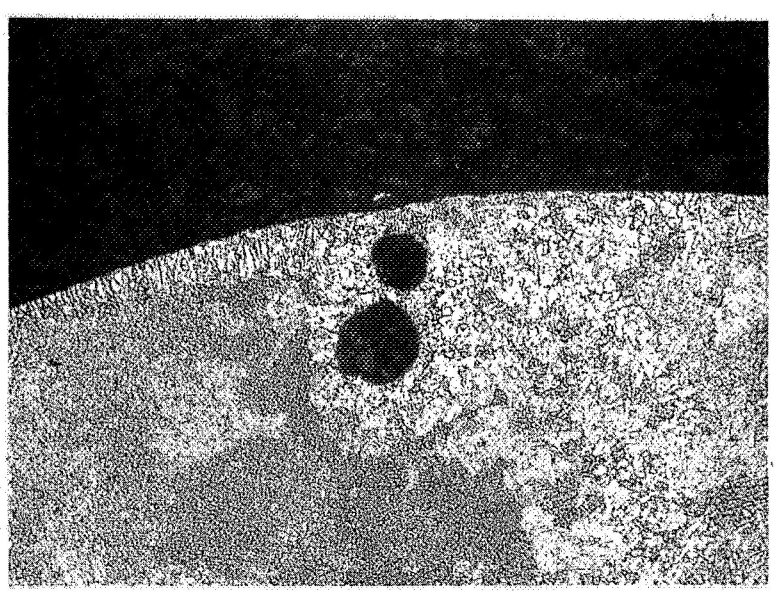
Figure 5b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



5 X MAG.
LINEAR POROSITY

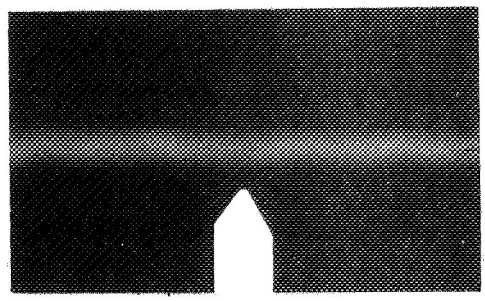


50 X MAG.

Figure 6a.

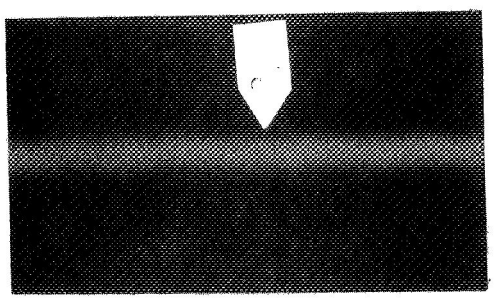
RADIOGRAPHS OF ALUMINUM WELDS

MAT. 2219
THICK. 0.125"

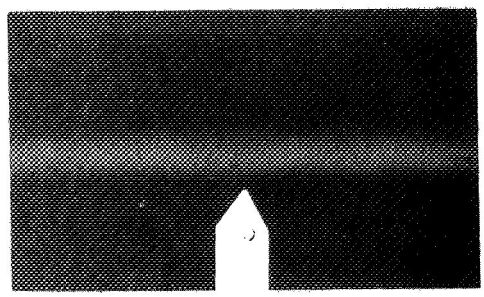


LINEAR POROSITY

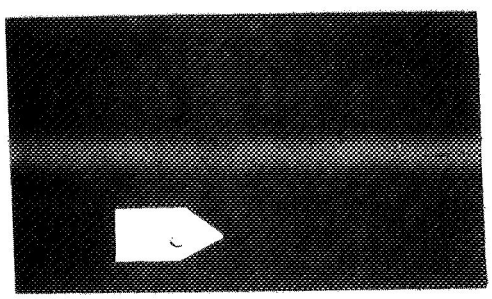
90°



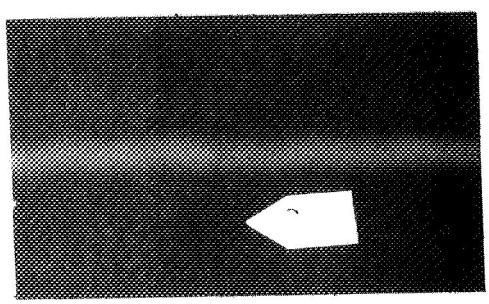
20° TL



20° TR



20° LL

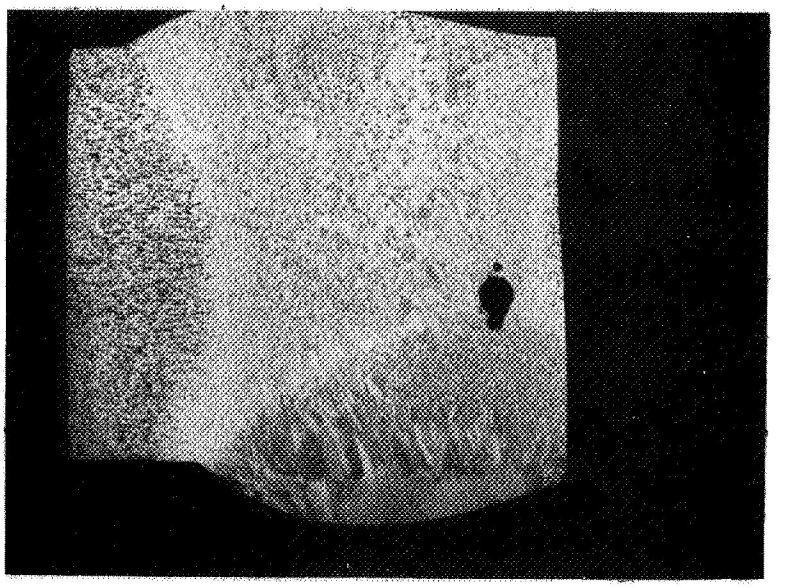


20° LR

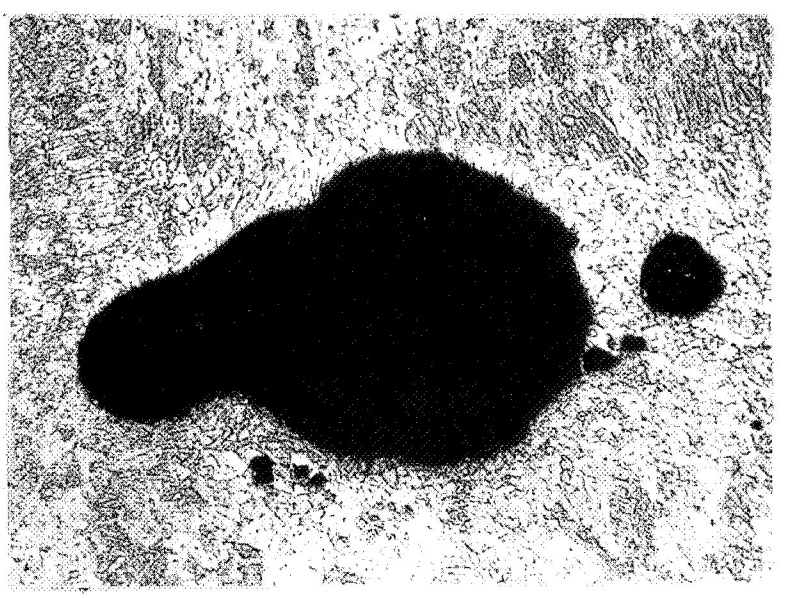
Figure 6b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



5 X MAG.
ISOLATED POROSITY

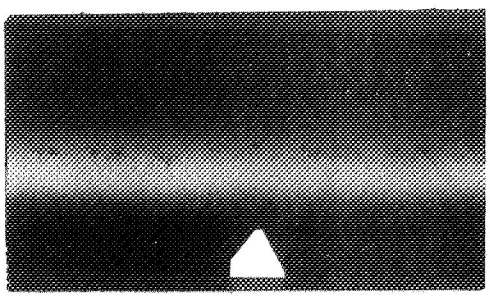


50 X MAG.

Figure 7a.

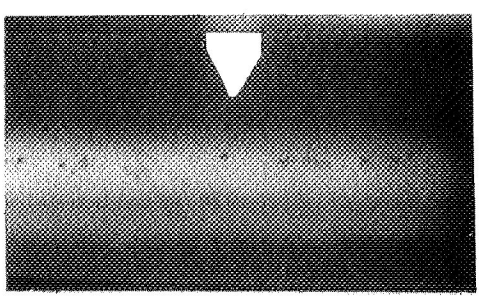
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 0.375"

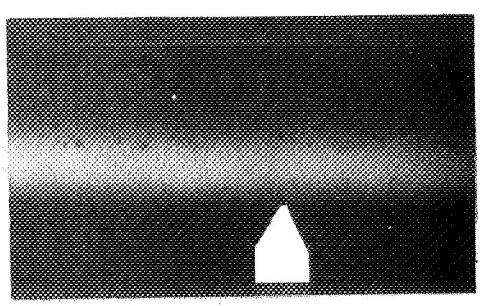


90°

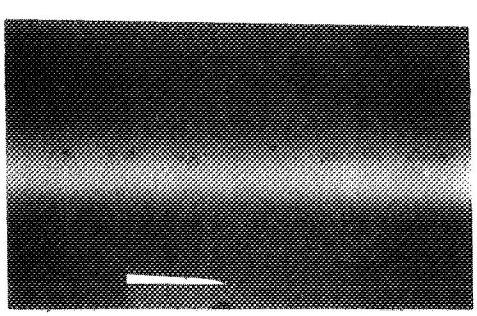
ISOLATED
POROSITY



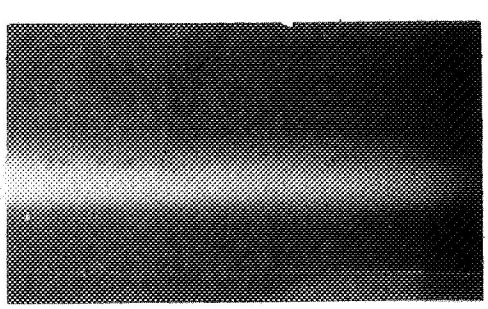
20°TL



20°TR



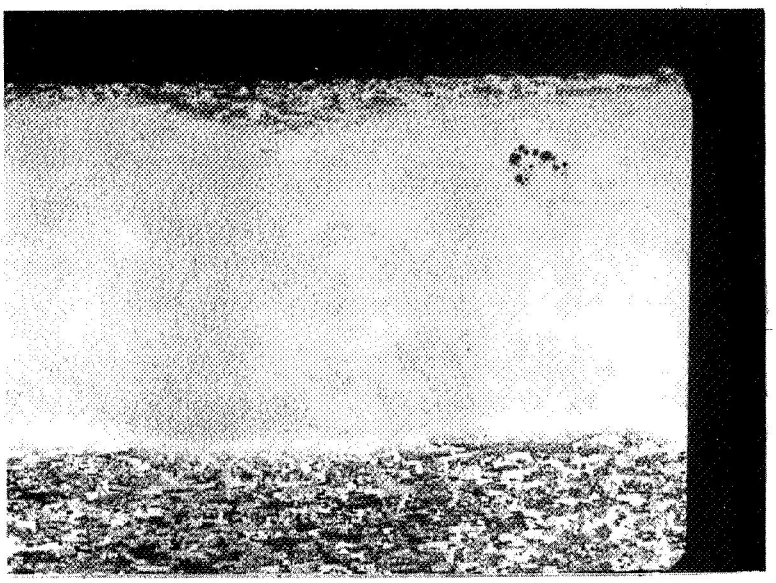
20°LL



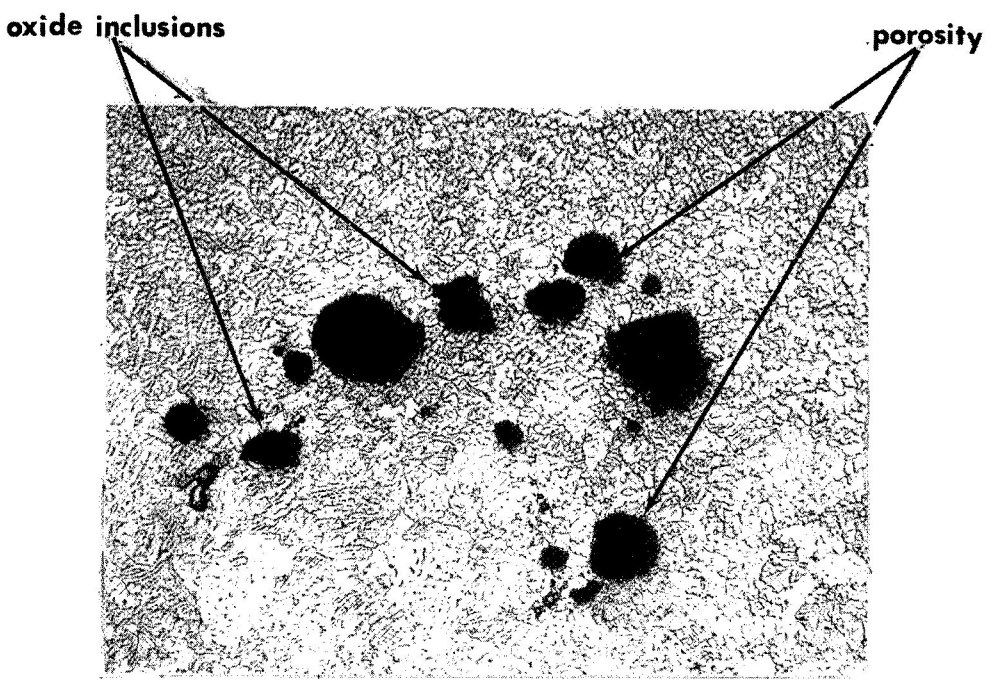
20°LR

Figure 7b.

PHOTOMACROGRAPHS
PARALLEL SECTION



5 X MAG.
SCATTERED POROSITY and OXIDE INCLUSIONS

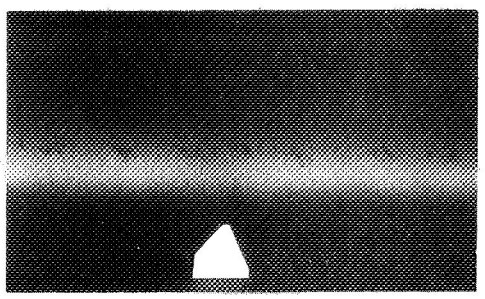


50 X MAG.

Figure 8a.

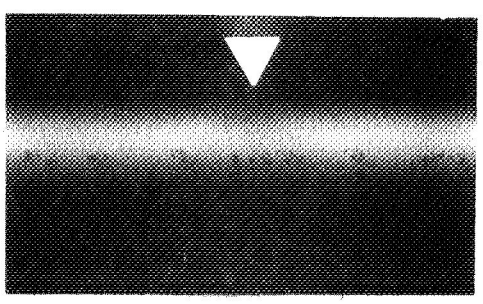
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 0.375"

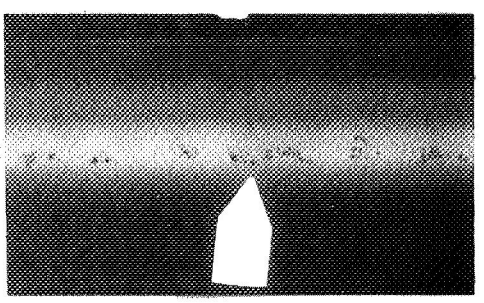


SCATTERED POROSITY
and
OXIDE INCLUSIONS

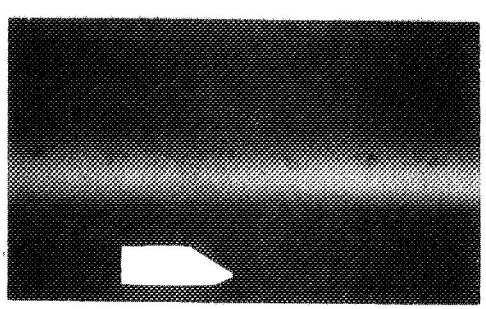
90°



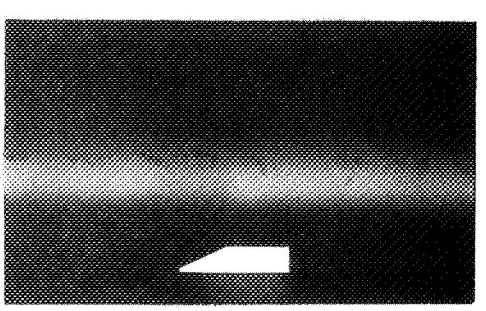
20°TL



20°TR



20°LL

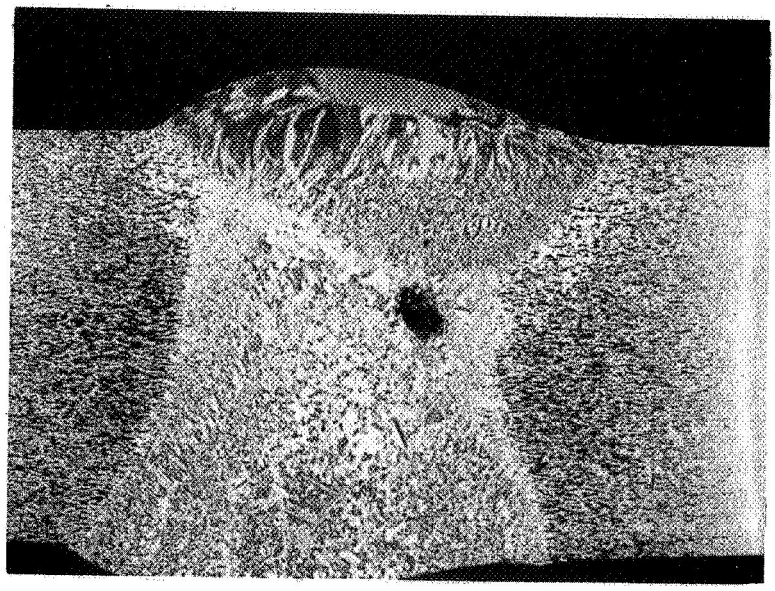


20°LR

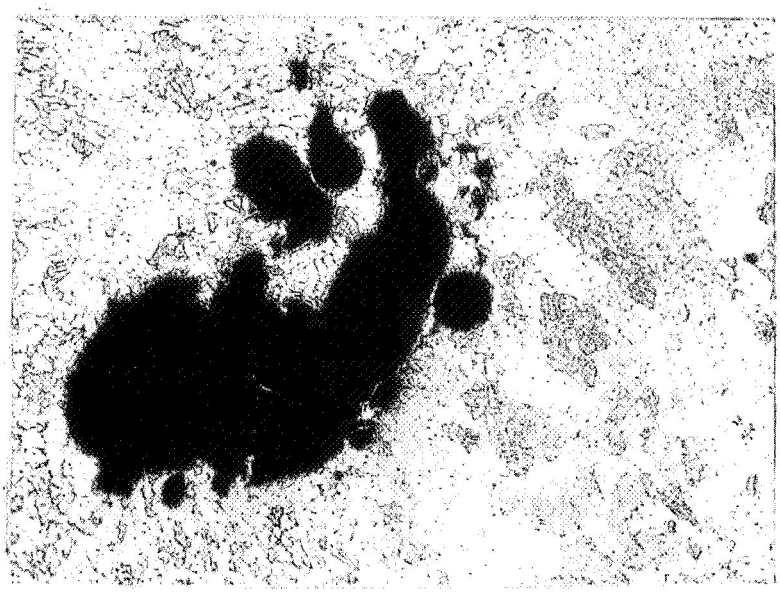
Figure 8b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



5 X MAG.
OXIDE INCLUSIONS

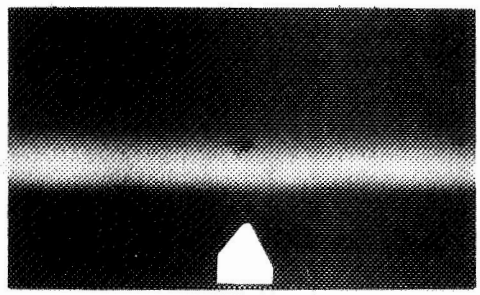


50 X MAG.

Figure 9a.

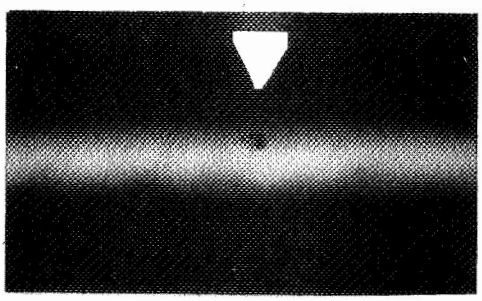
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 0.375"

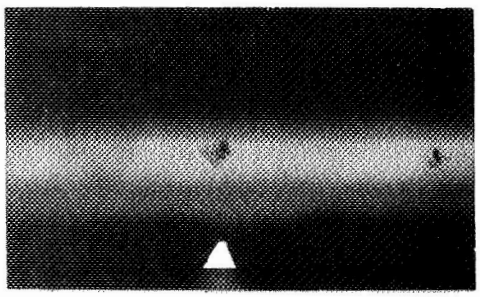


OXIDE INCLUSIONS

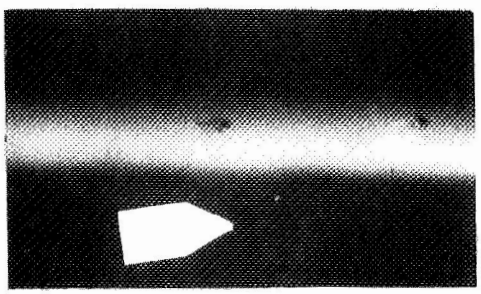
90°



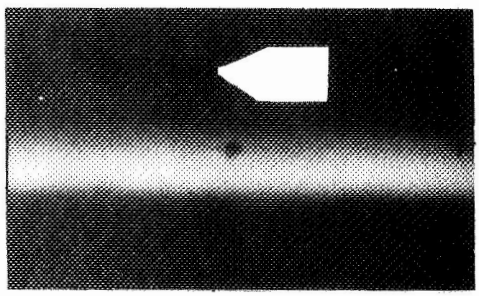
20°TL



20°TR



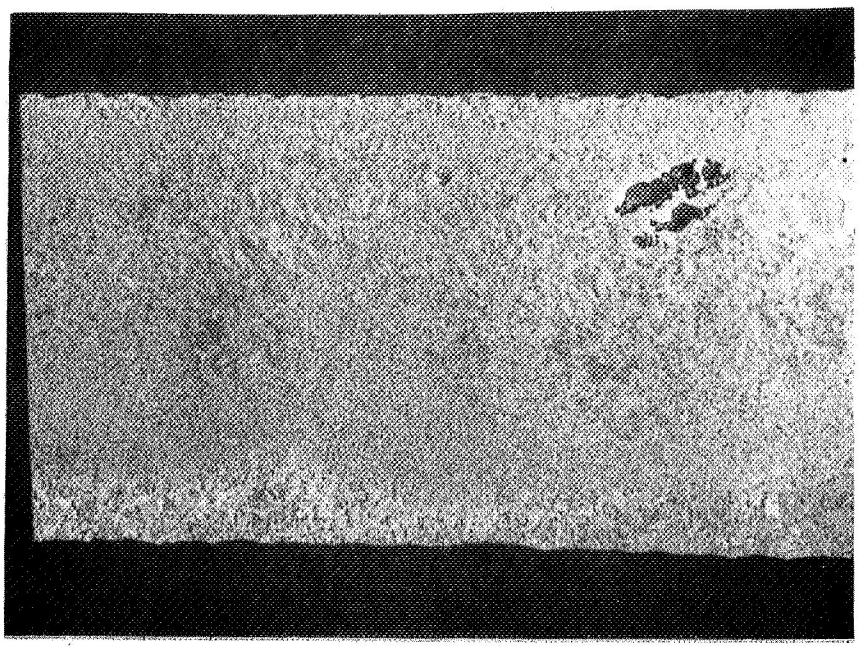
20°LL



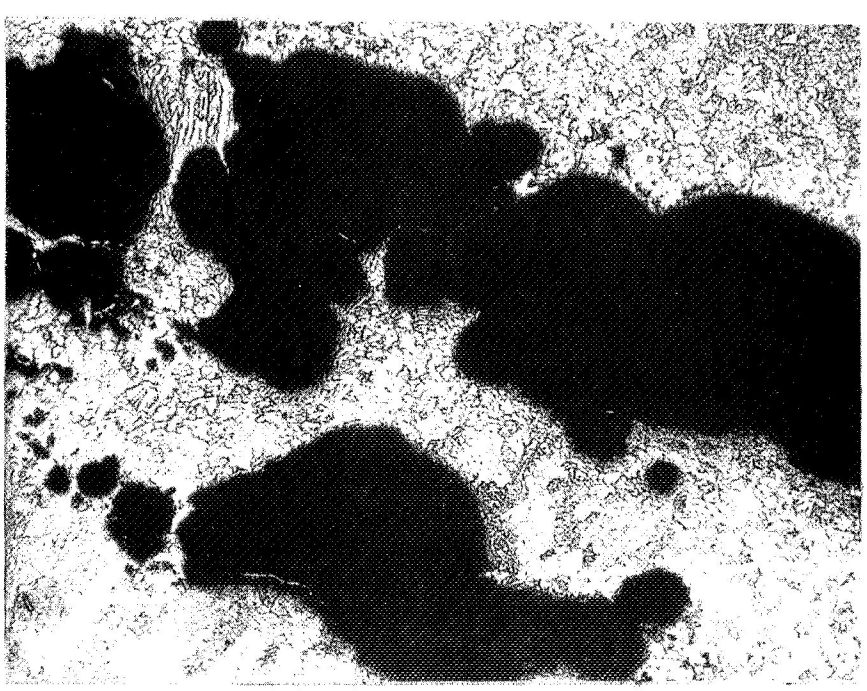
20°LR

Figure 9b.

PHOTOMACROGRAPHS
PARALLEL SECTION



5 X MAG.
OXIDE INCLUSIONS

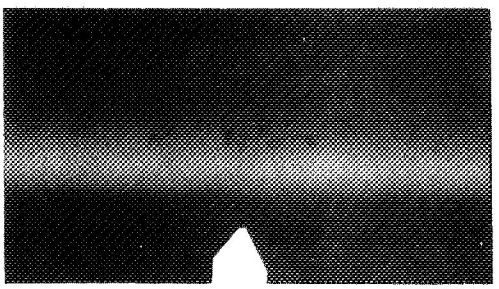


50 X MAG.

Figure 10a.

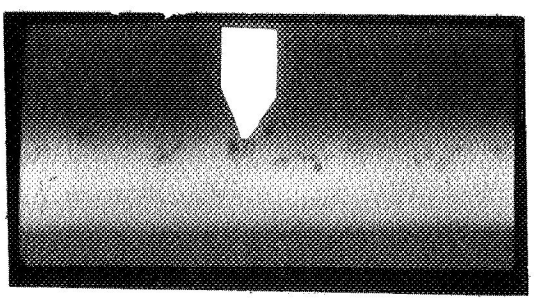
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 0.500"

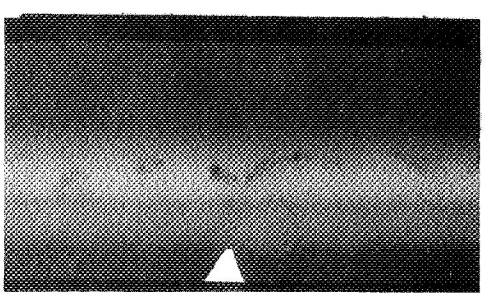


OXIDE
INCLUSIONS

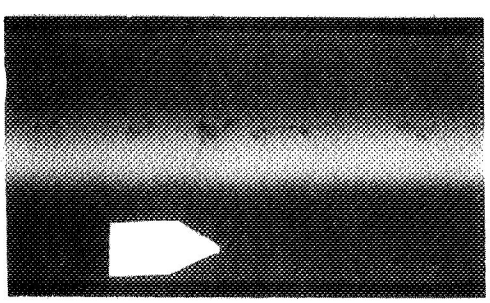
90°



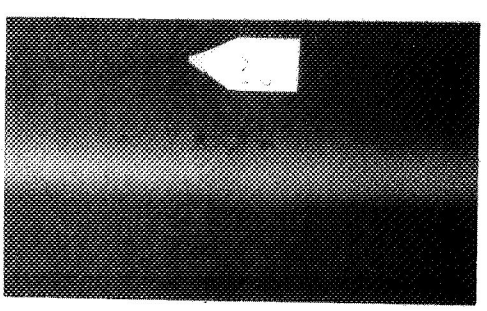
20°TL



20°TR



20°LL

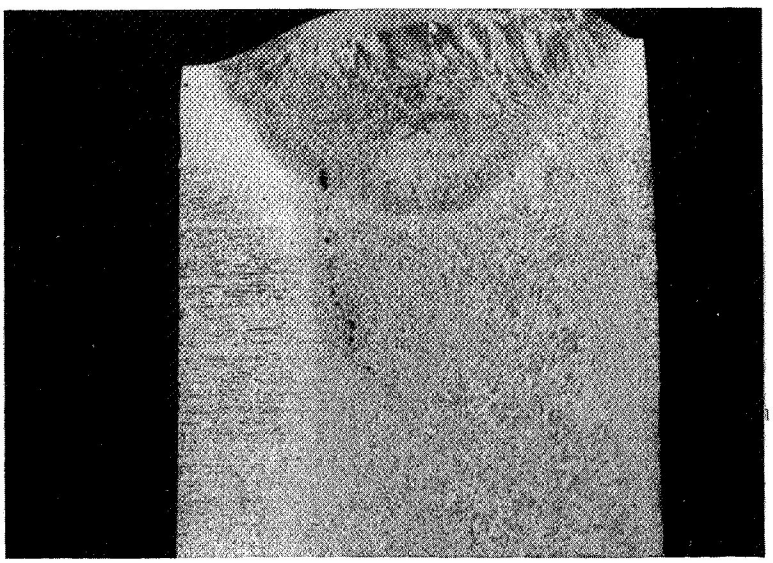


20°LR

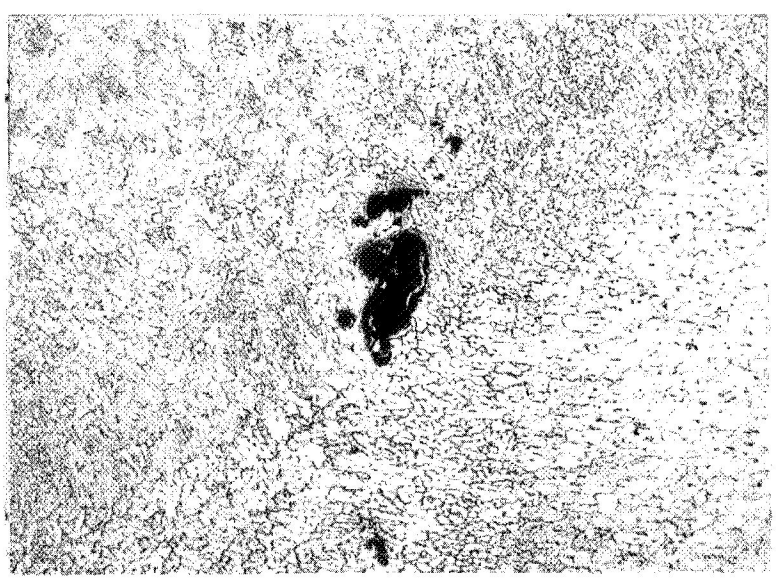
Figure 10b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



5 X MAG.
INCOMPLETE FUSION

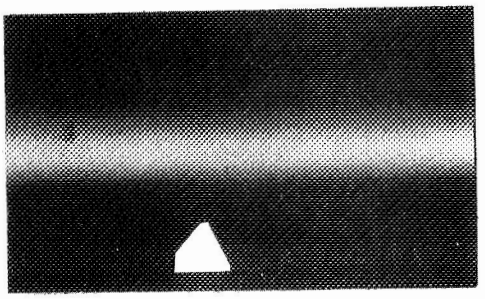


50 X MAG.

Figure 11a.

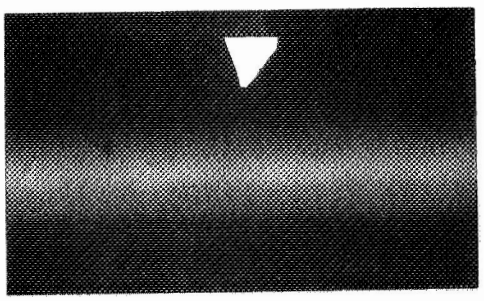
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 0.500"

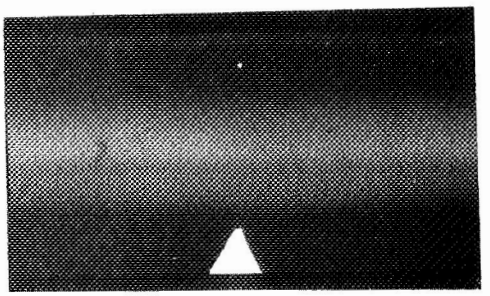


INCOMPLETE
FUSION

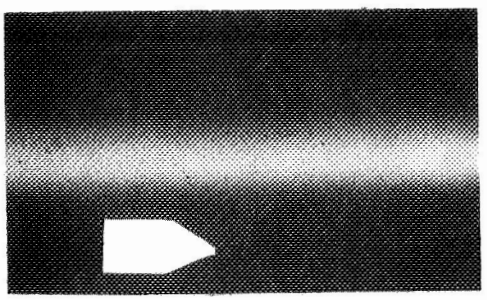
90°



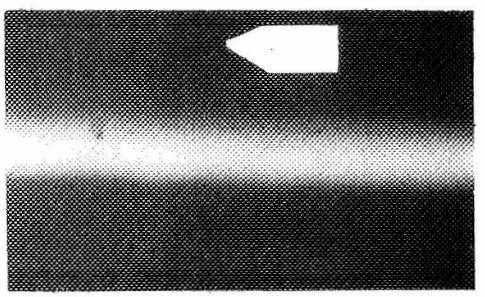
20° TL



20° TR



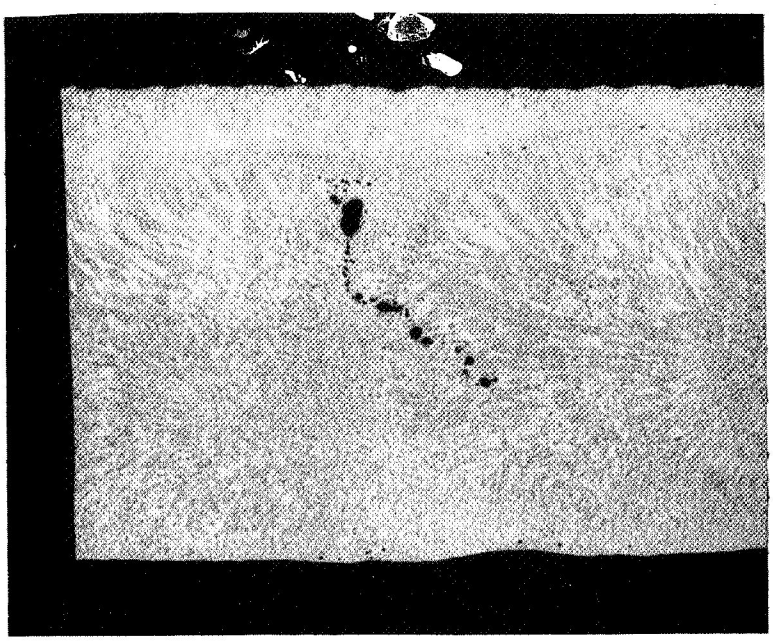
20° LL



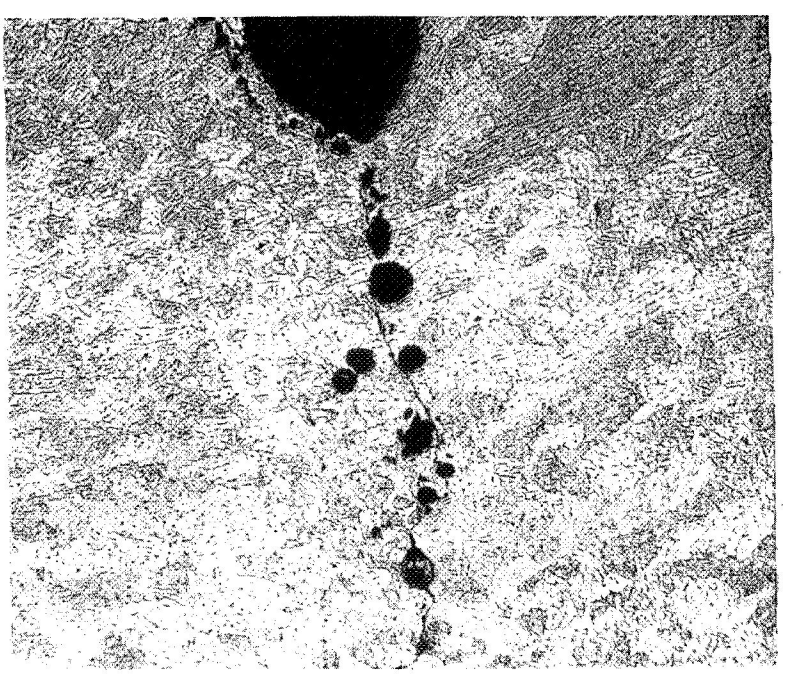
20° LR

Figure 11b.

PHOTOMACROGRAPHS
PARALLEL SECTION



5 X MAG.
TRANSVERSE CRACK

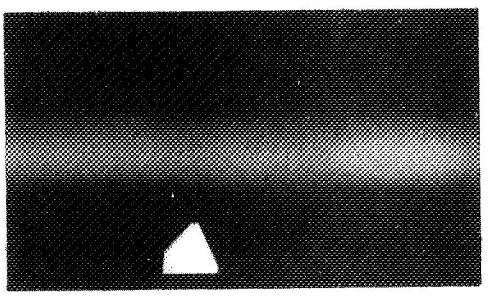


50 X MAG.

Figure 12a.

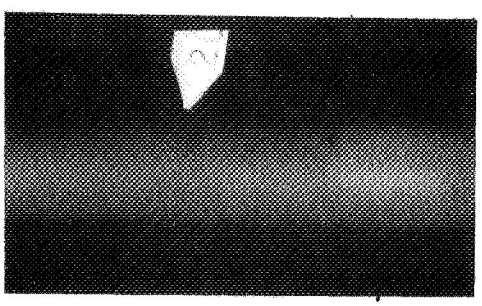
RADIOGRAPHS OF ALUMINUM WELDS

MAT. 2219
THICK. 0.500"

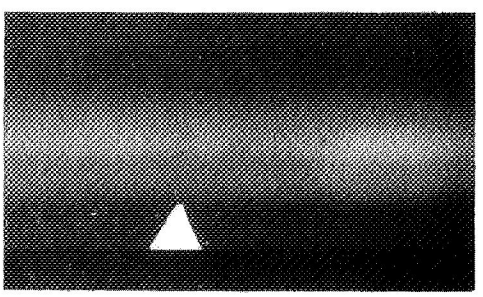


TRANSVERSE CRACK

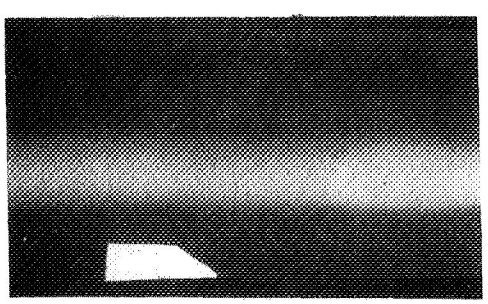
90°



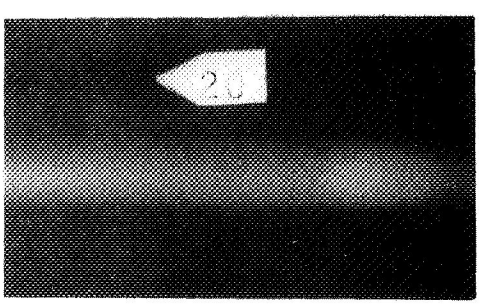
20°TL



20°TR



20°LL

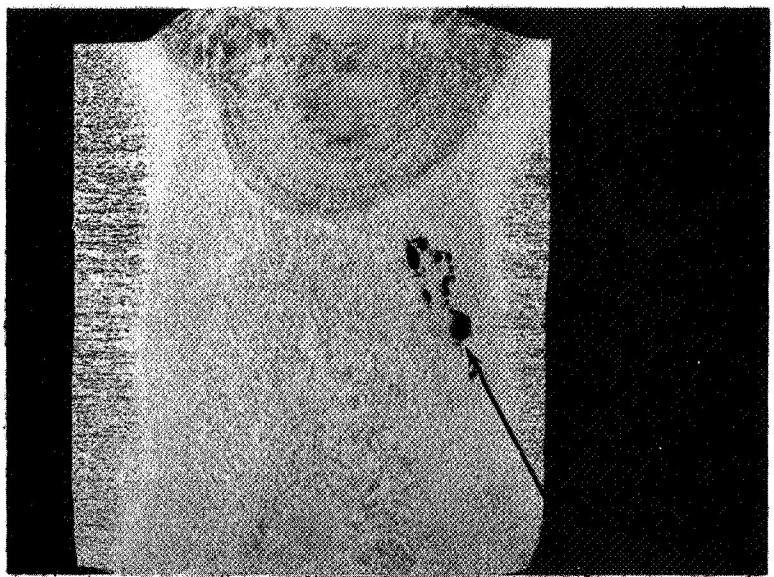


20°LR

Figure 12b.

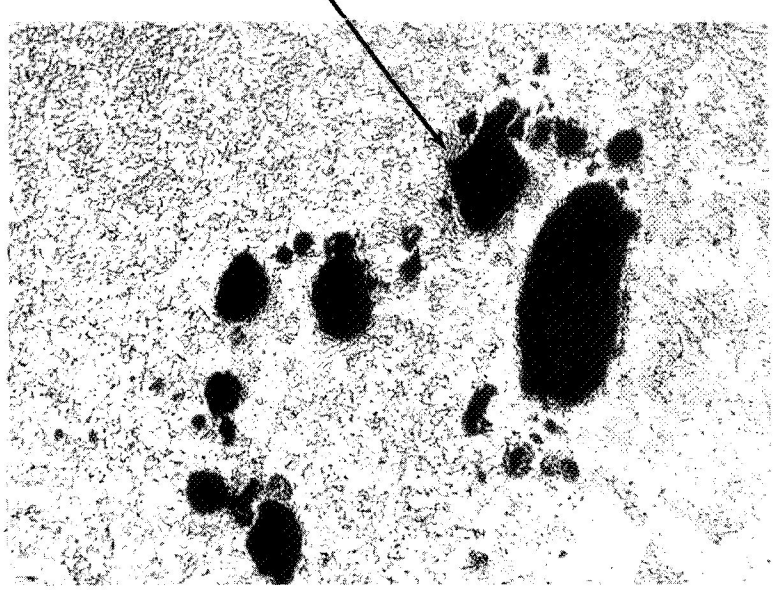
PHOTOMACROGRAPHS

TRANSVERSE SECTION



5 X MAG.

SHARP ANGLED and TAILED INCLUSIONS POROSITY

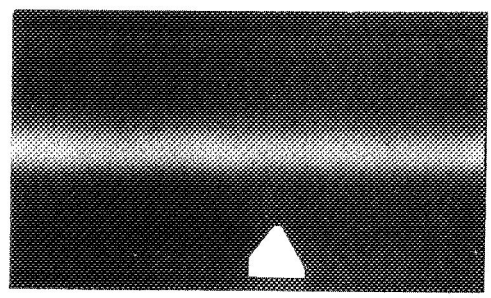


50 X MAG.

Figure 13a.

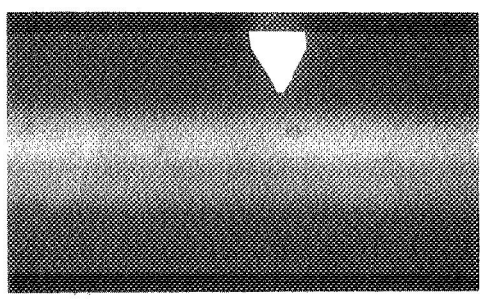
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 0.500"

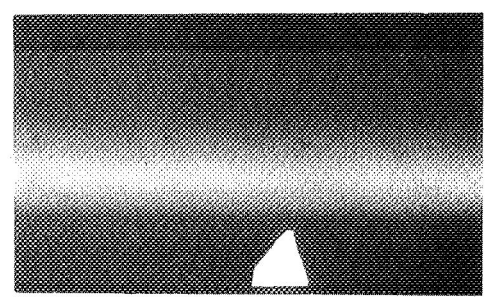


TAILED POROSITY

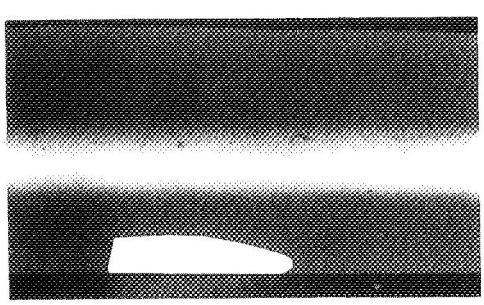
90°



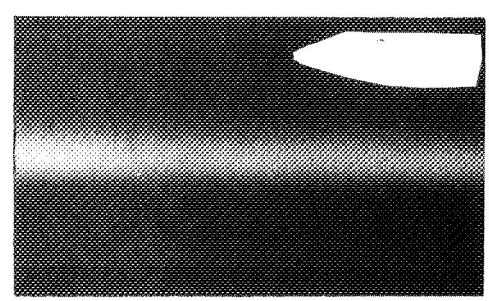
20°TL



20°TR



20°LL

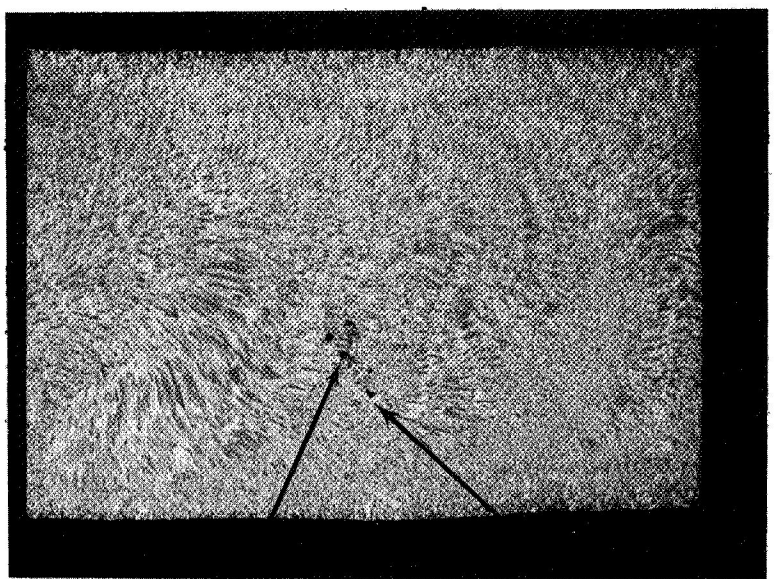


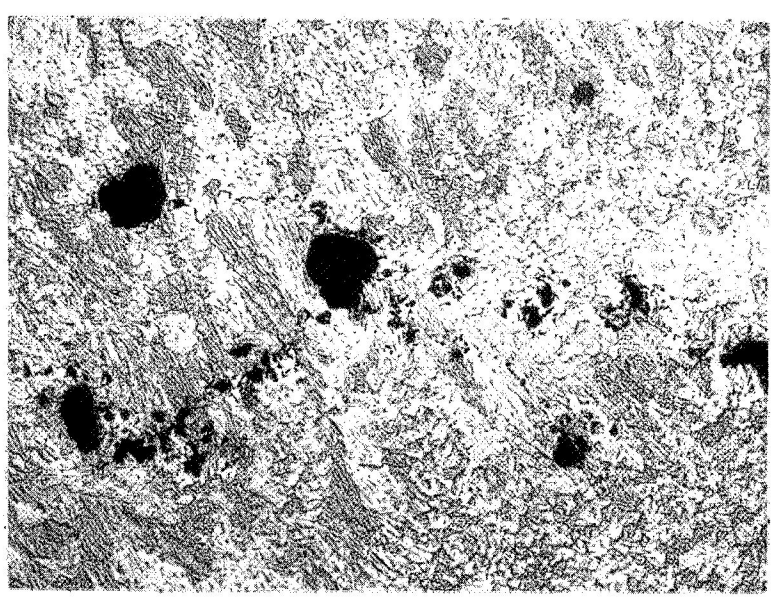
20°LR

Figure 13b.

PHOTOMACROGRAPHS

PLANED SECTION



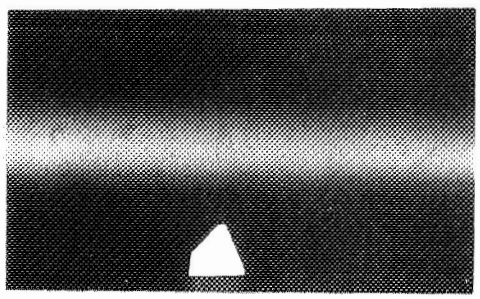


50 X MAG.

Figure 14a.

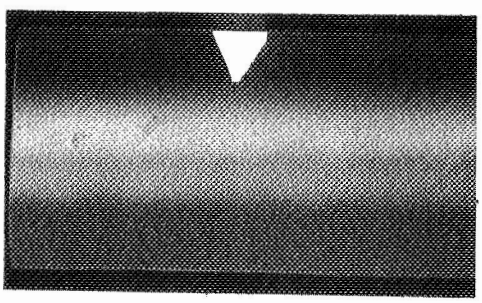
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 0.500"

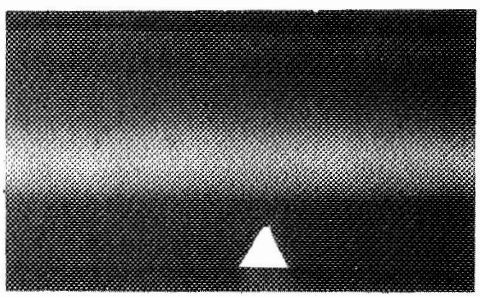


TAILED
POROSITY
and
OXIDE
INCLUSIONS

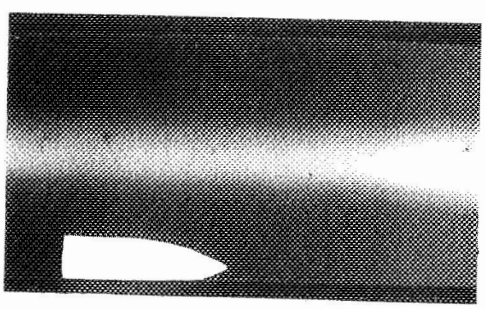
90°



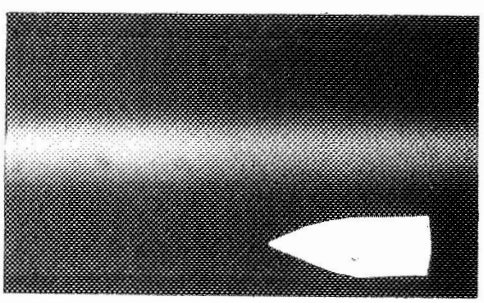
20°TL



20°TR



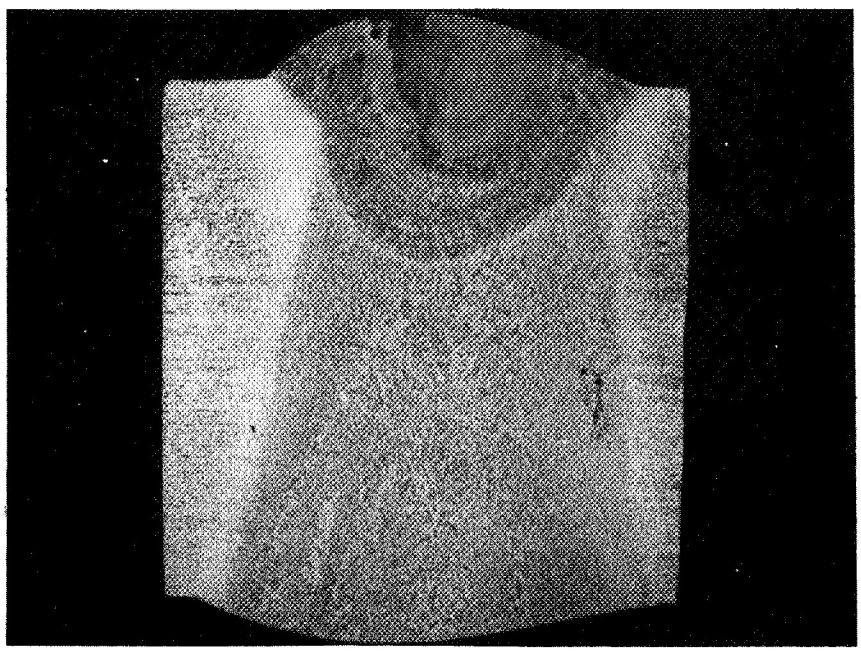
20°LL



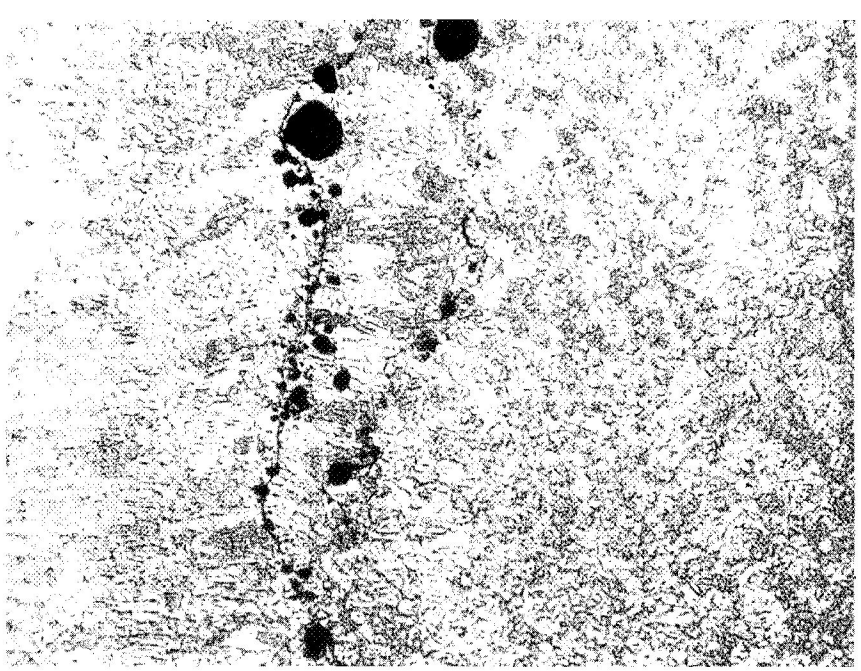
20°LR

Figure 14b.

PHOTOMACROGRAPHS
TRANSVERSE SECTION



5 X MAG.
POROSITY and OXIDE INCLUSIONS with CRACK

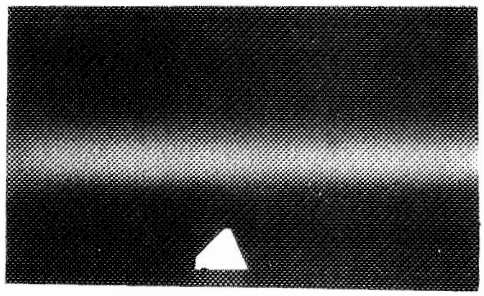


50 X MAG.

Figure 15a.

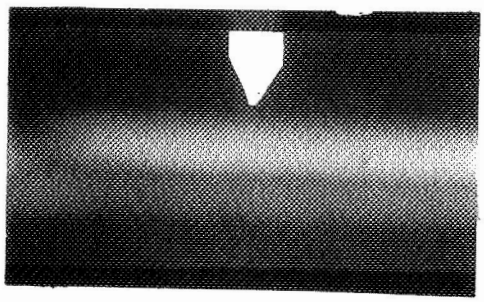
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 0.500"

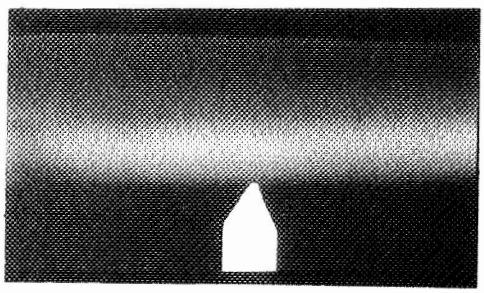


ENIGMA

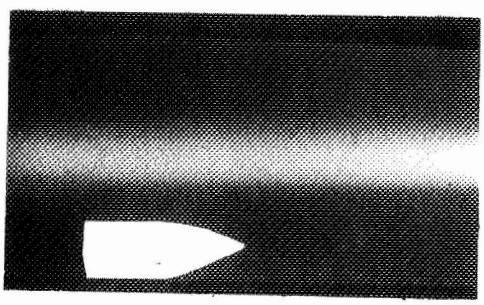
90°



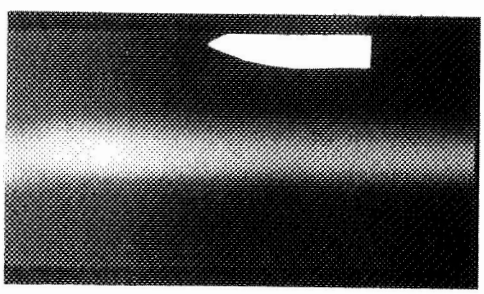
20°TL



20°TR



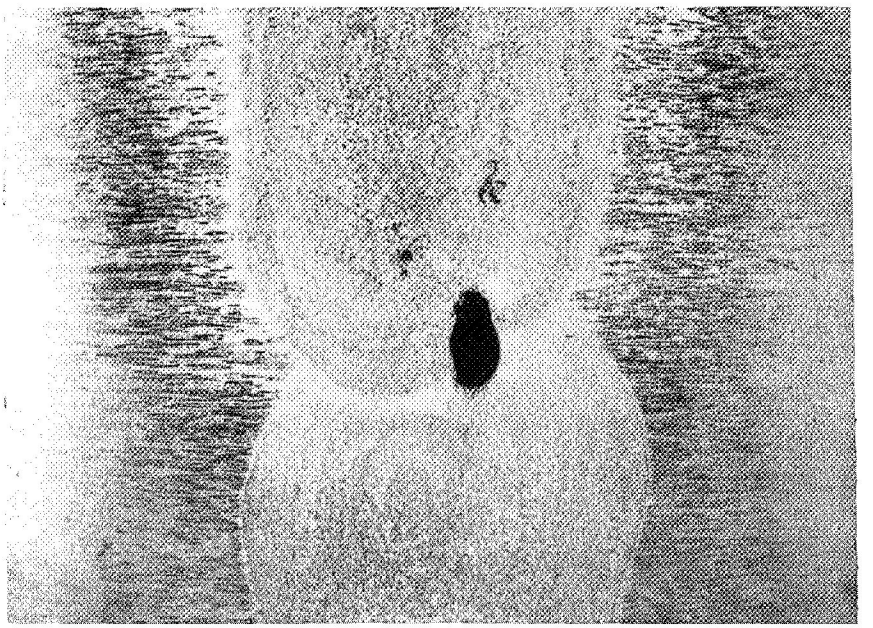
20°LL



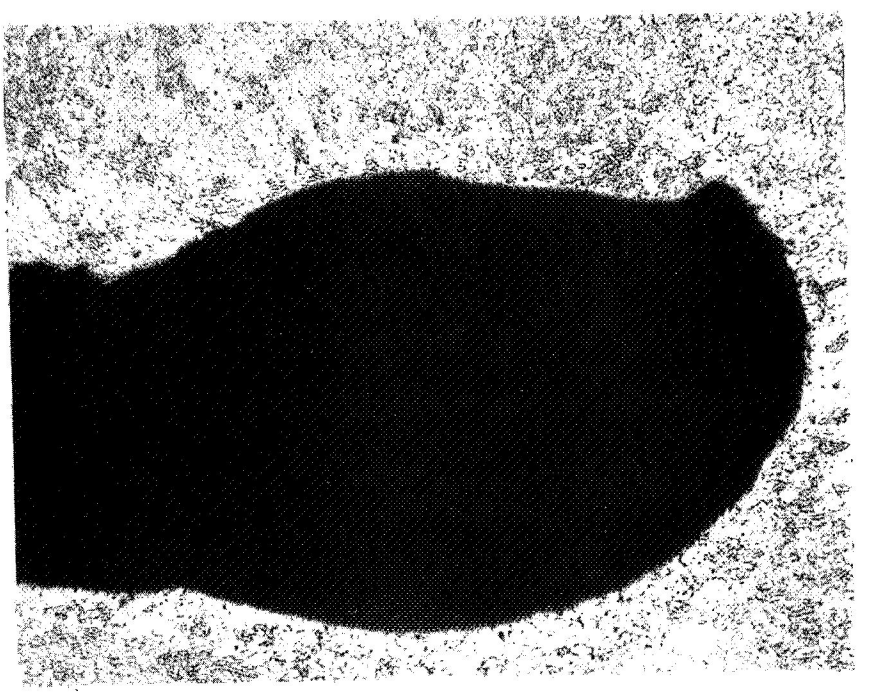
20°LR

Figure 15b.

PHOTOMACROGRAPHS
TRANSVERSE SECTION



5 X MAG.
ISOLATED POROSITY

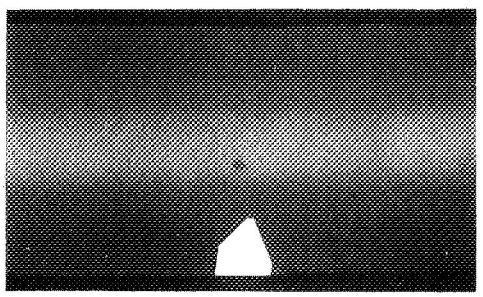


50 X MAG.

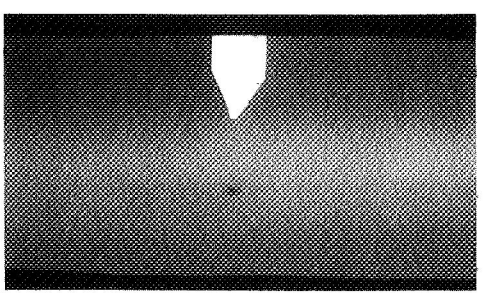
Figure 16a.

RADIOGRAPHS
OF
ALUMINUM WELDS

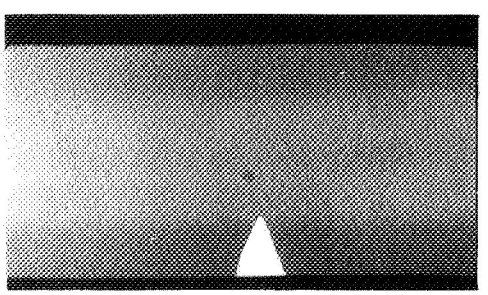
MAT. 2219
THICK. 0.750"



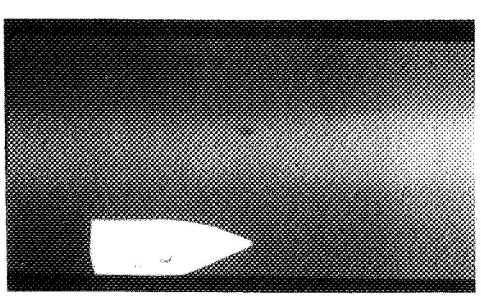
ISOLATED
POROSITY



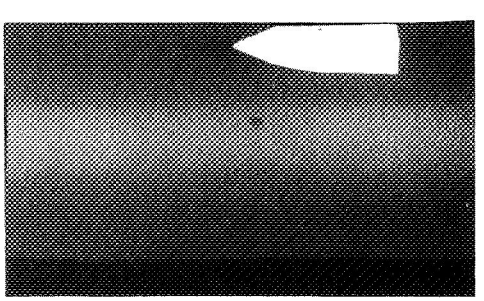
20°TL



20°TR



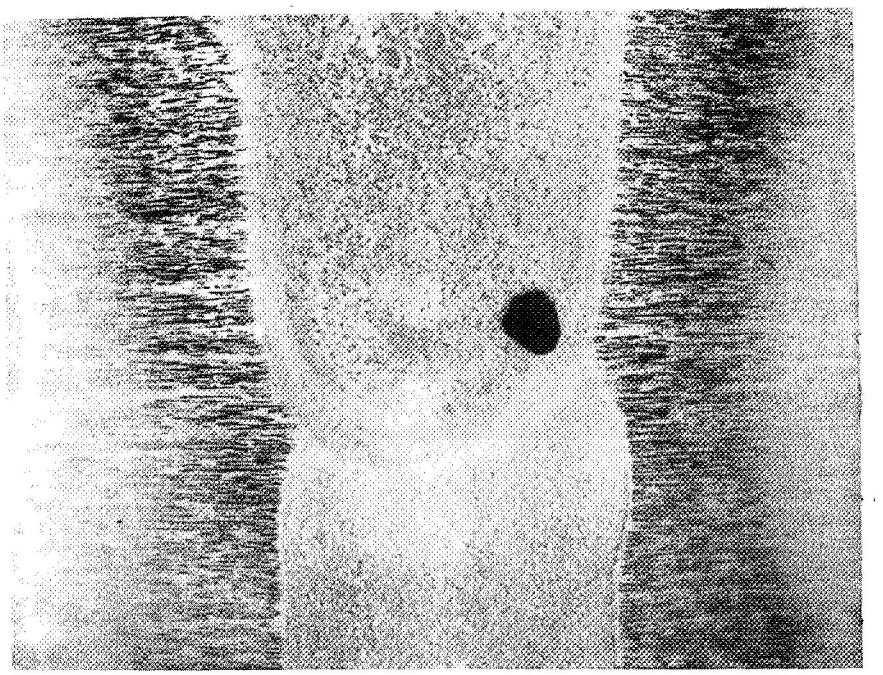
20°LL



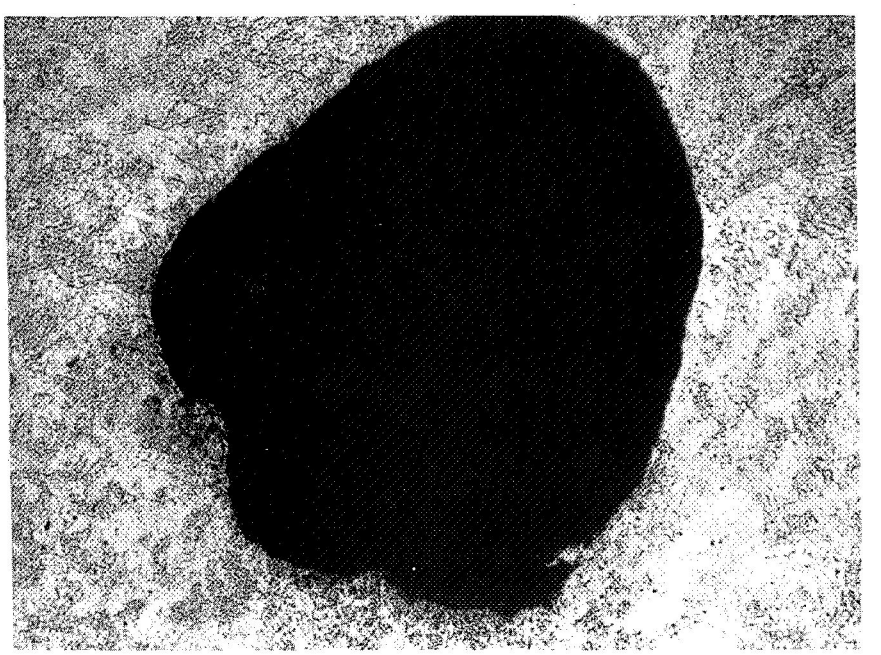
20°LR

Figure 16b.

PHOTOMACROGRAPHS
TRANSVERSE SECTION



5 X MAG.
ISOLATED POROSITY

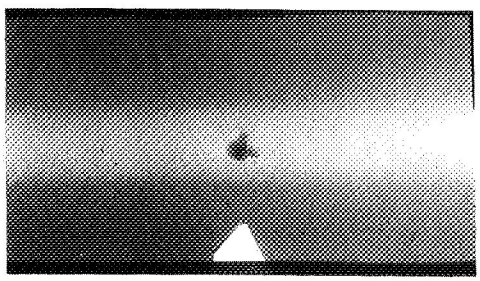


50 X MAG.

Figure 17a.

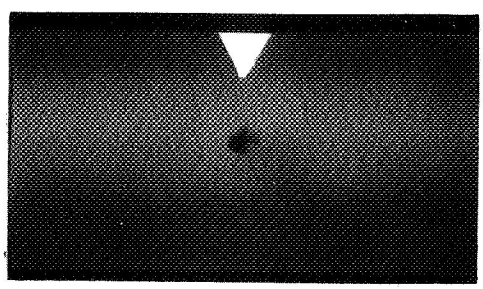
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 0.750"

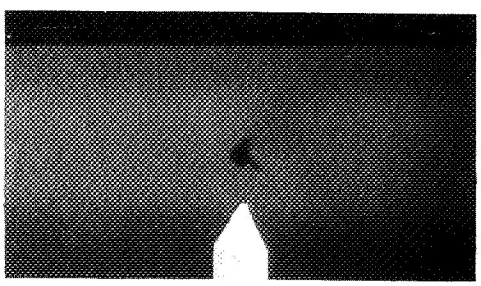


ISOLATED
POROSITY

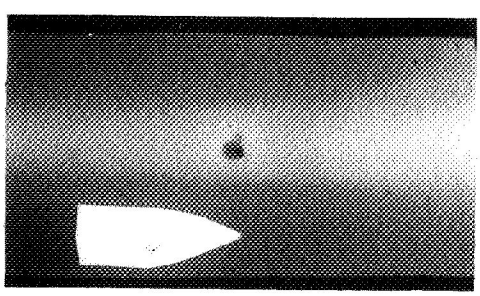
90°



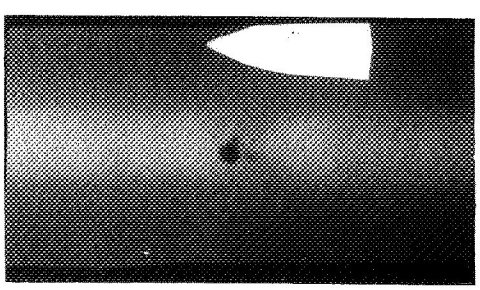
20°TL



20°TR



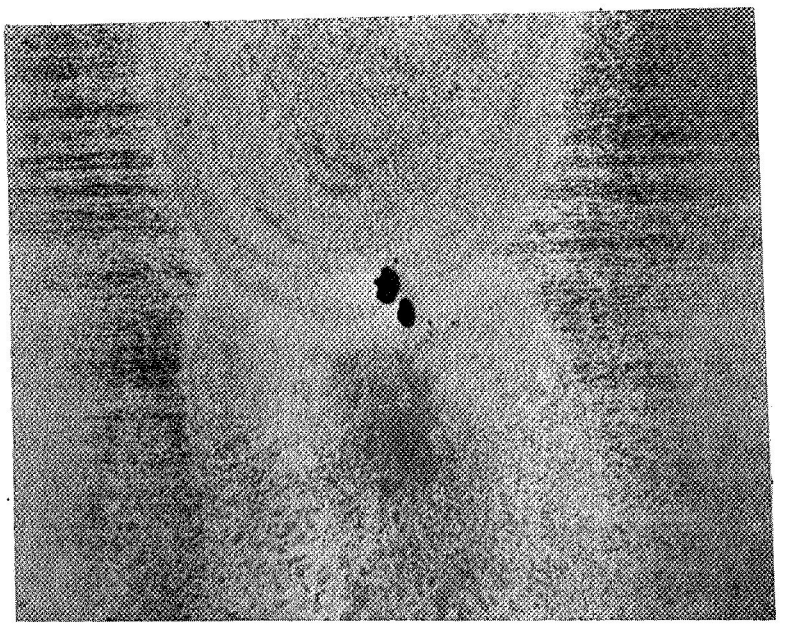
20°LL



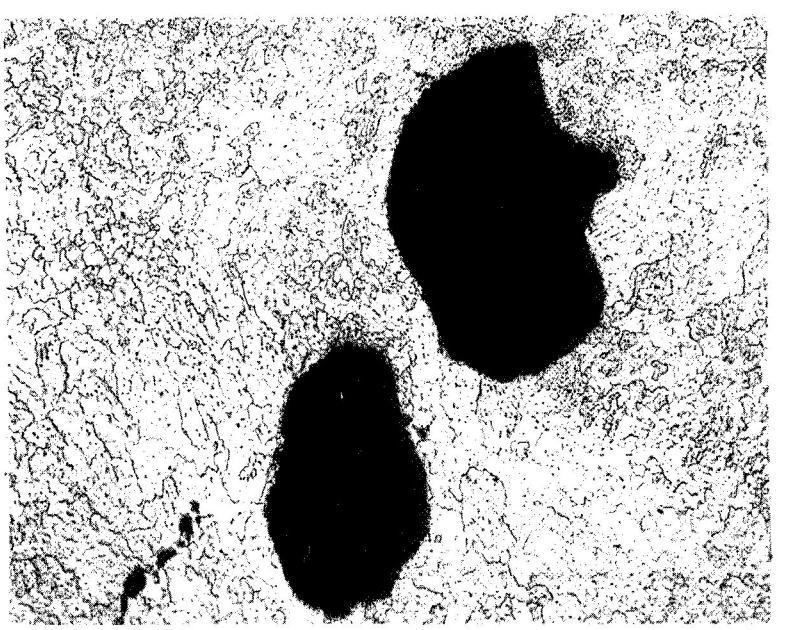
20°LR

Figure 17b.

PHOTOMACROGRAPHS
TRANSVERSE SECTION



5 X MAG.
POROSITY

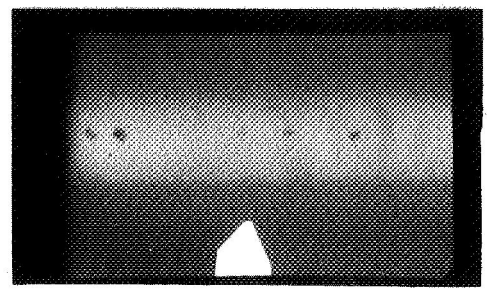


50 X MAG.

Figure 18a.

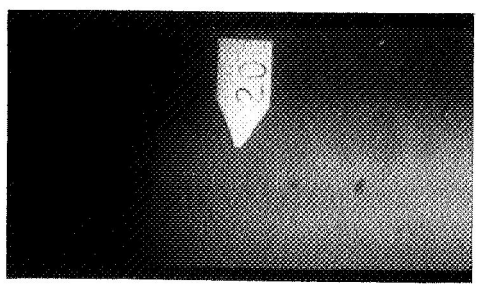
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 1.00"

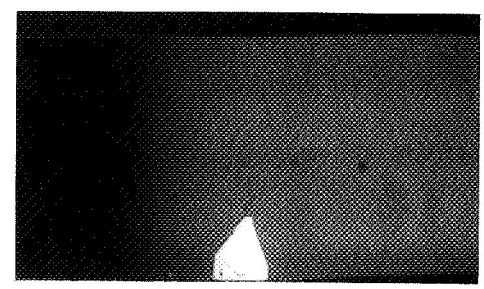


POROSITY

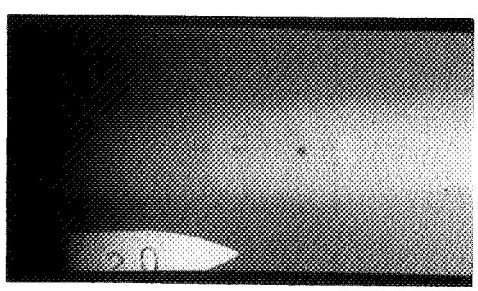
90°



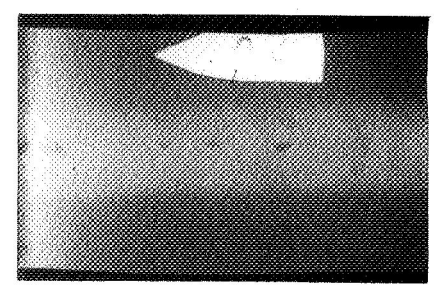
20°TL



20°TR



20°LL

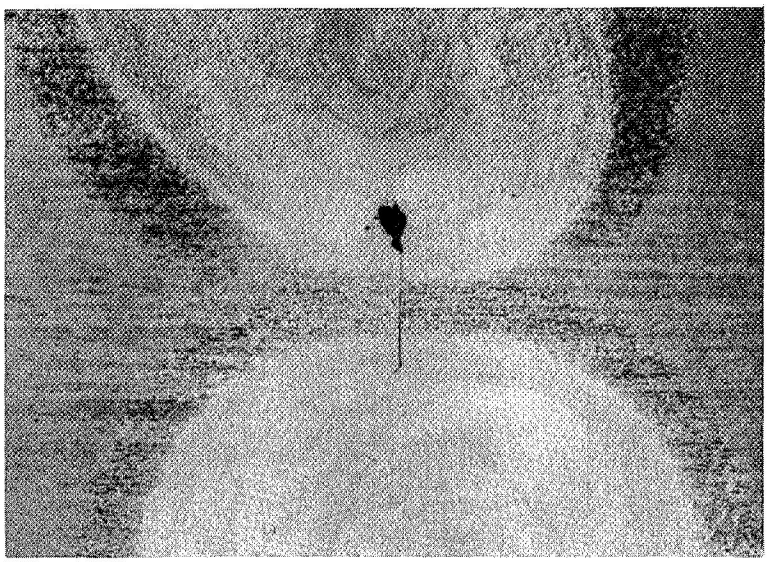


20°LR

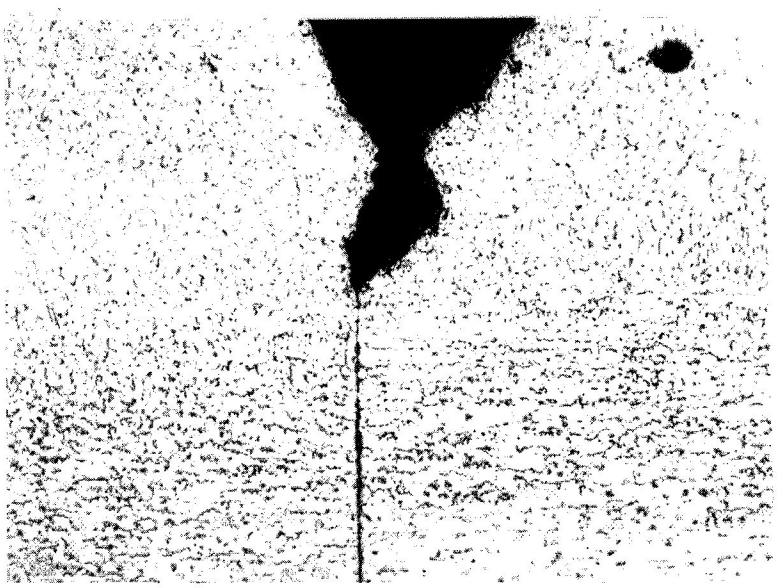
Figure 18b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



5 X MAG.
INCOMPLETE PENETRATION
OXIDE INCLUSION

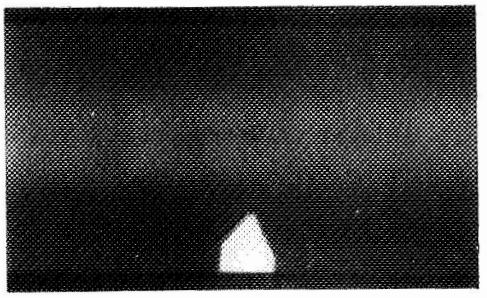


50 X MAG.

Figure 19a.

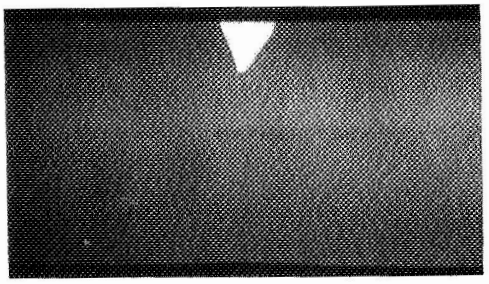
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 1.00"

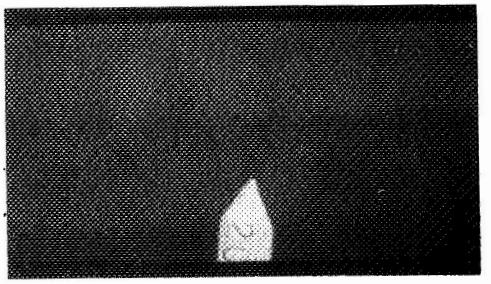


90°

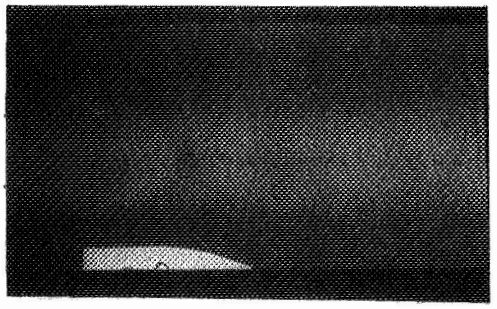
INCOMPLETE PENETRATION
OXIDE INCLUSIONS



20°TL



20°TR



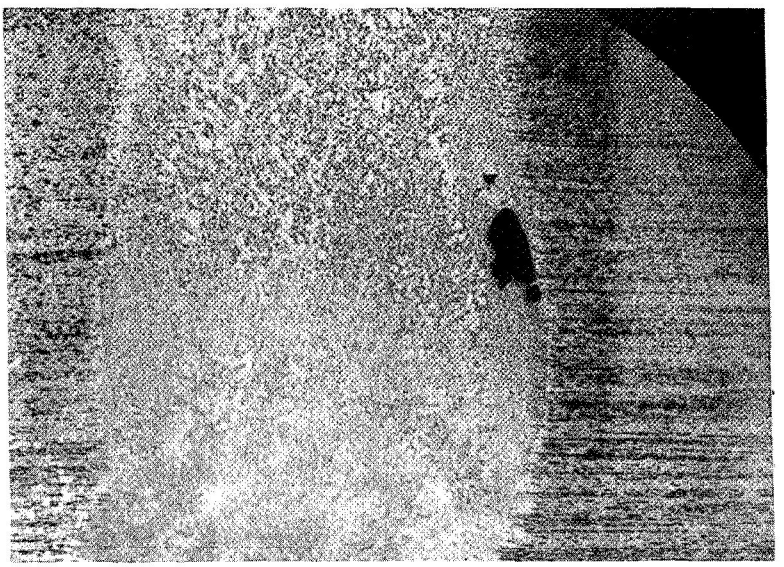
20°LL

20°LR

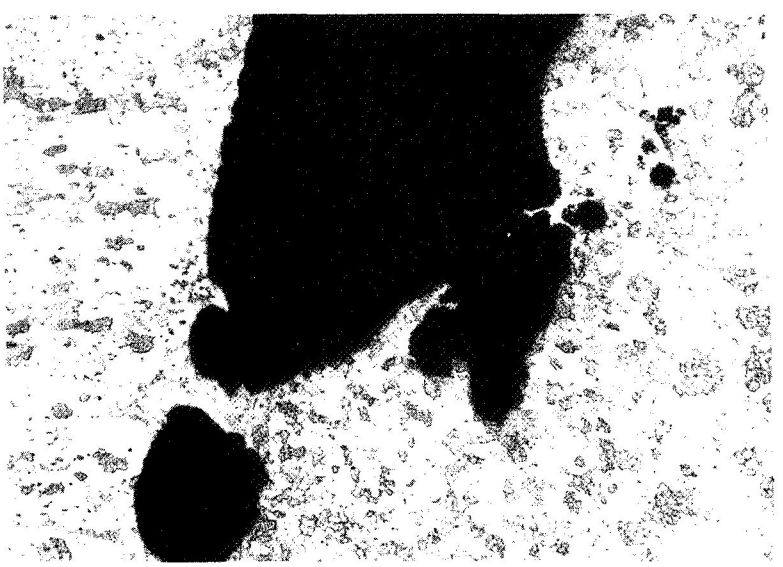
Figure 19b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



5 X MAG.
TAILED POROSITY

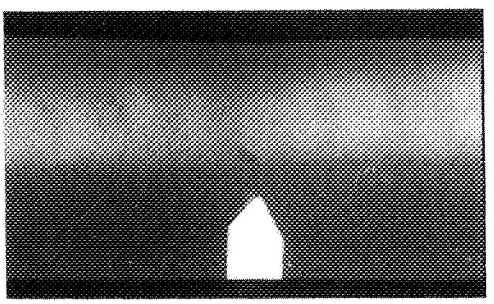


50 X MAG.

Figure 20a.

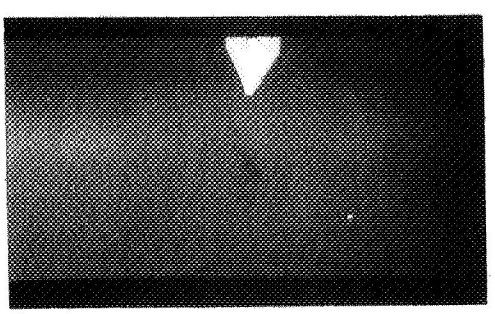
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 1.00"

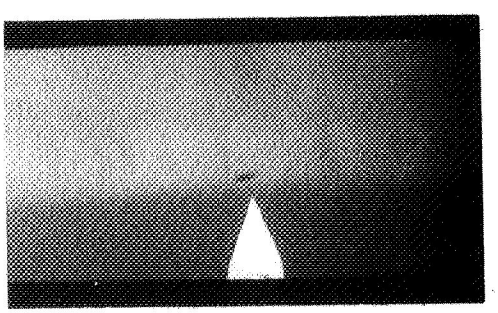


TAILED
POROSITY

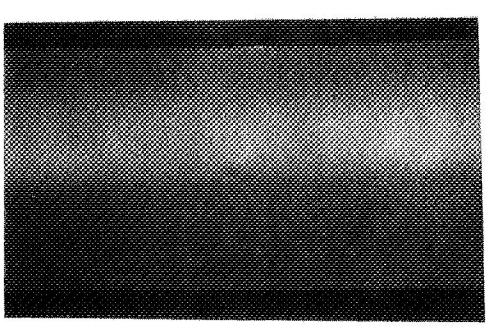
90°



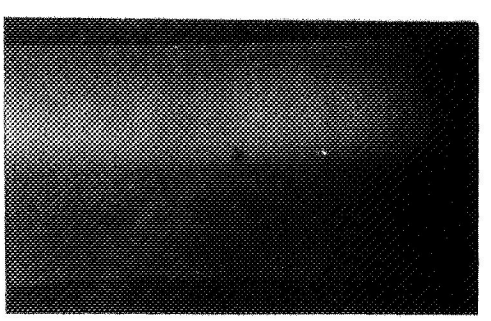
20°TL



20°TR



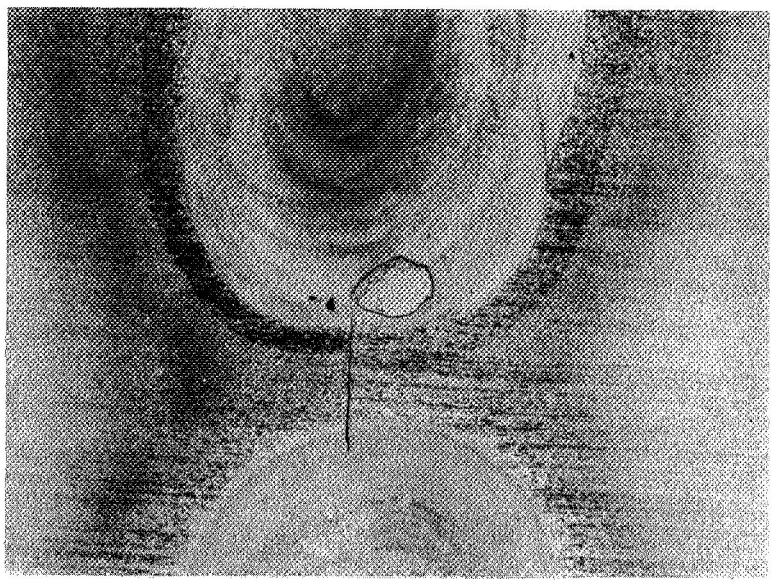
20°LL



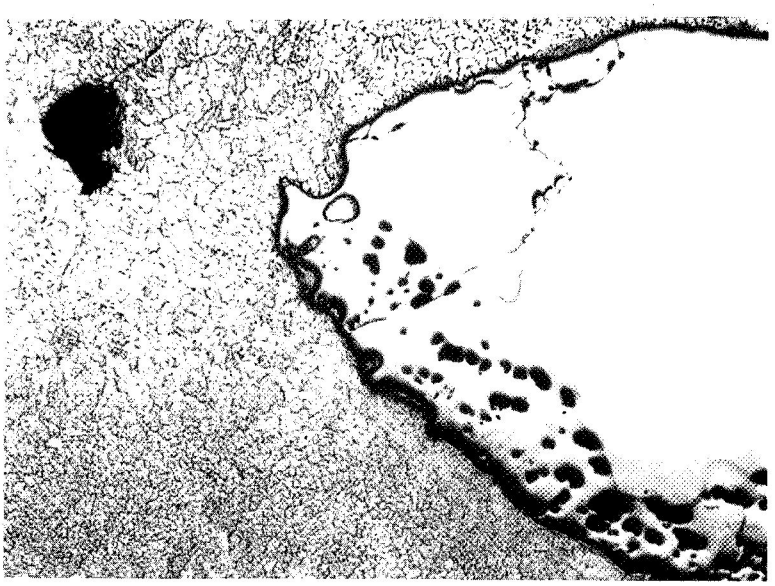
20°LR

Figure 20b.

PHOTOMACROGRAPHS
TRANSVERSE SECTION



5 X MAG.
MORE DENSE INCLUSION
TUNGSTEN
INCOMPLETE PENETRATION

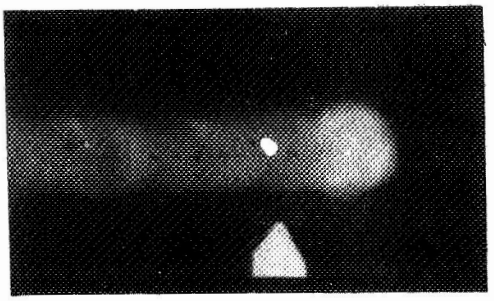


50 X MAG.

Figure 21a.

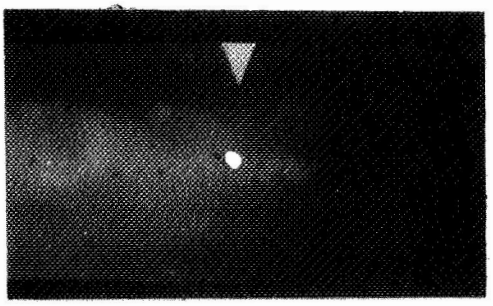
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 1.00"

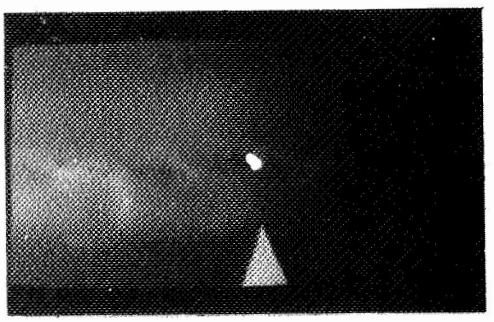


MORE DENSE
INCLUSION, TUNGSTEN
INCOMPLETE
PENETRATION

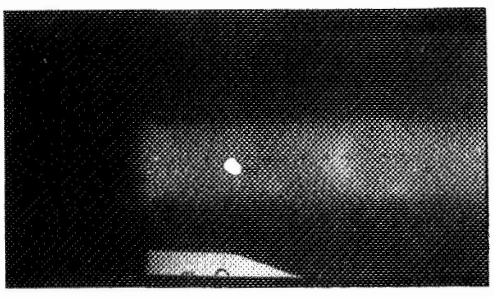
90°



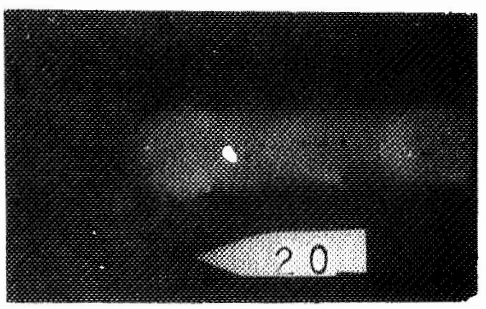
20°TL



20°TR



20°LL



20°LR

Figure 21b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION

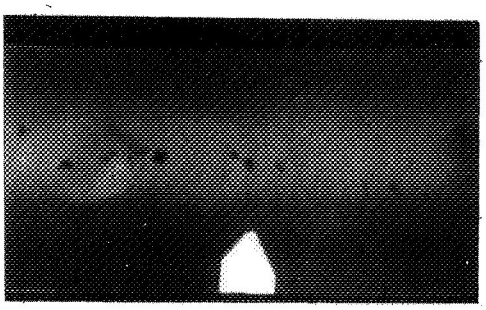
5 X MAG.
TAILED POROSITY

50 X MAG.

Figure 22a.

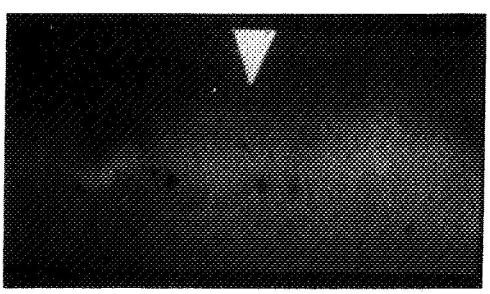
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 1.00"

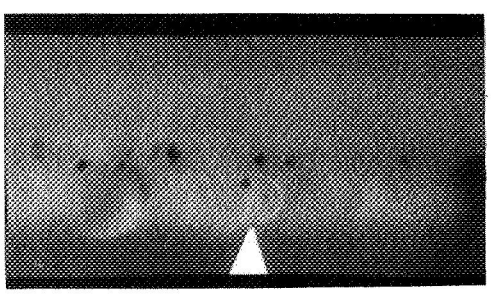


TAILED
POROSITY

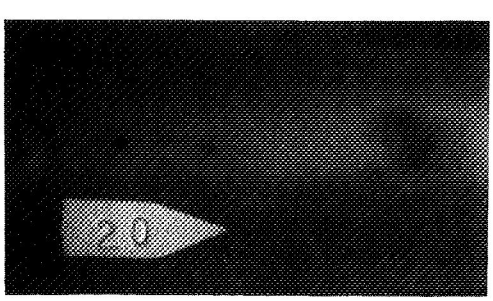
90°



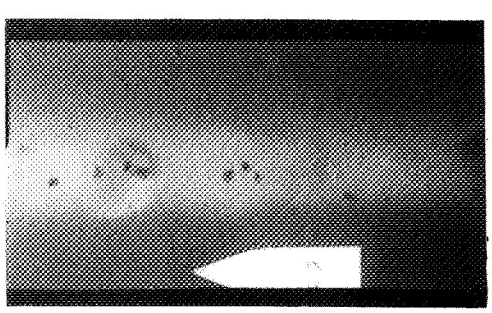
20°TL



20°TR



20°LL

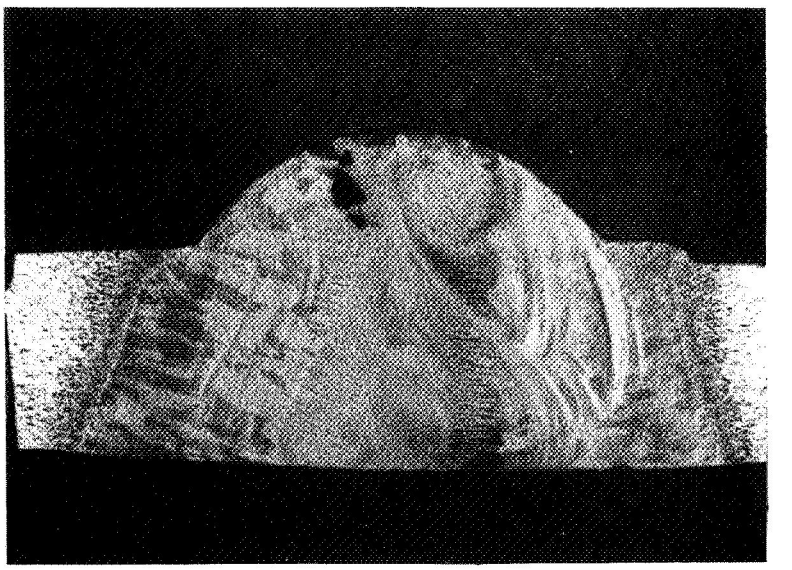


20°LR

Figure 22b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



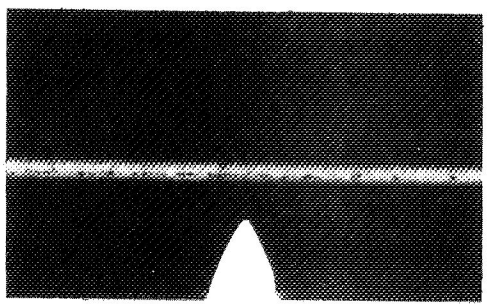
15 X MAG.
LINEAR POROSITY

50 X MAG.

Figure 23a.

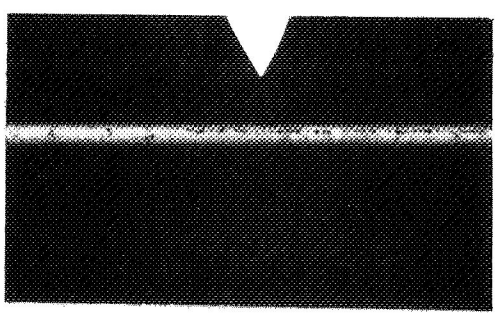
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2014
THICK. 0.063"

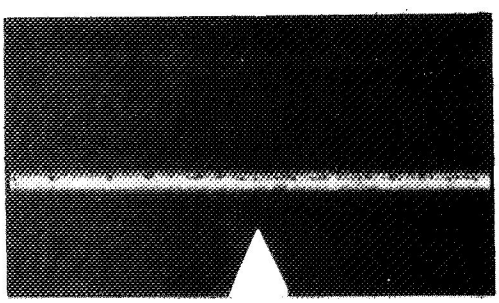


LINEAR POROSITY

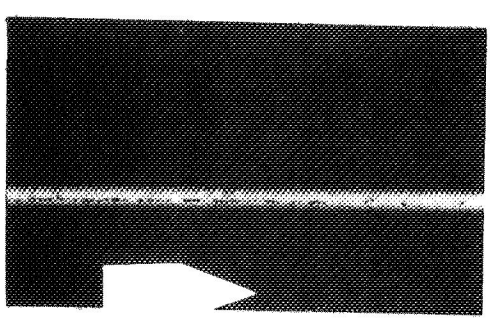
90°



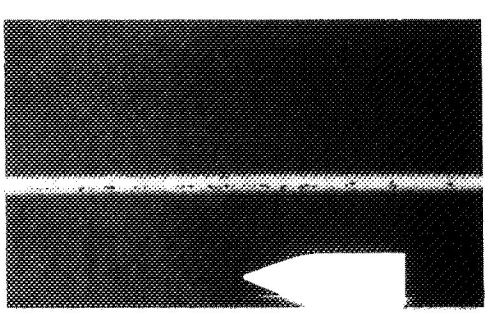
20°TL



20°TR



20°LL

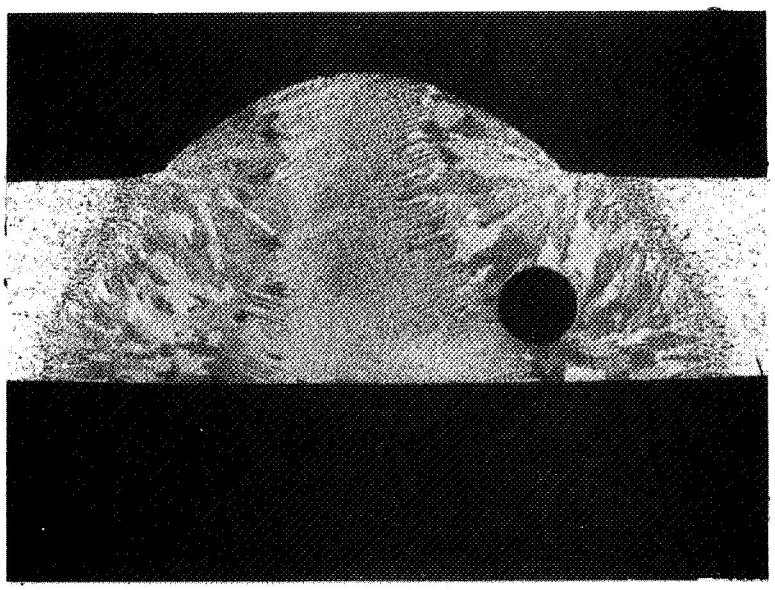


20°LR

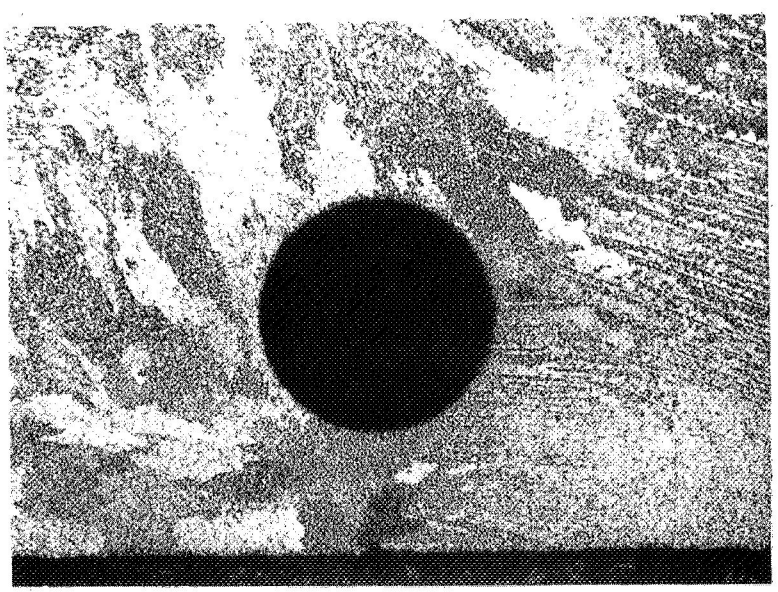
Figure 23b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



15 X MAG.
ISOLATED POROSITY

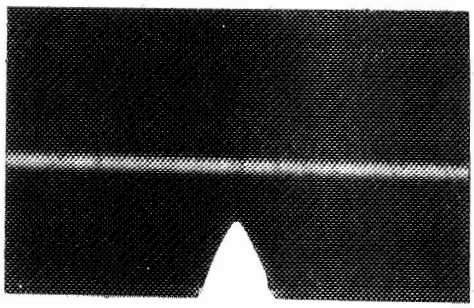


50 X MAG.

Figure 24a.

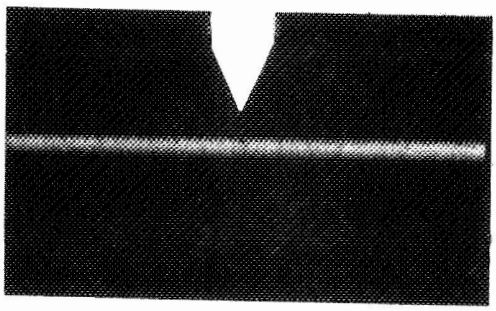
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2014
THICK. 0.063"

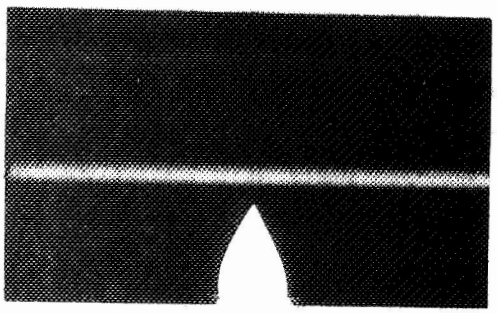


ISOLATED POROSITY

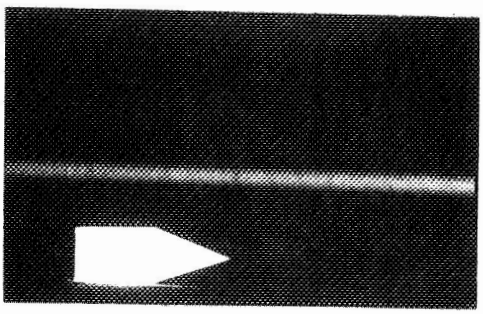
90°



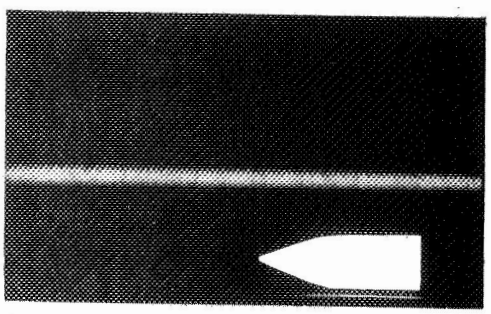
20°TL.



20°TR



20°LL

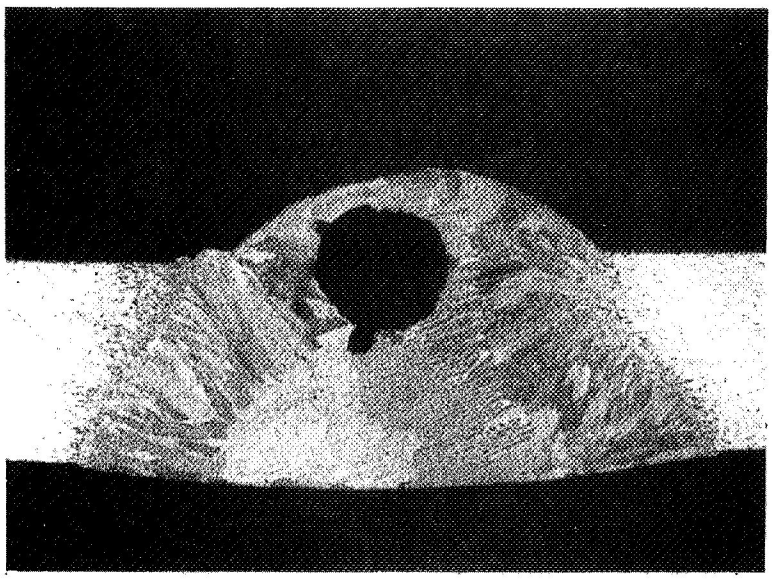


20°LR

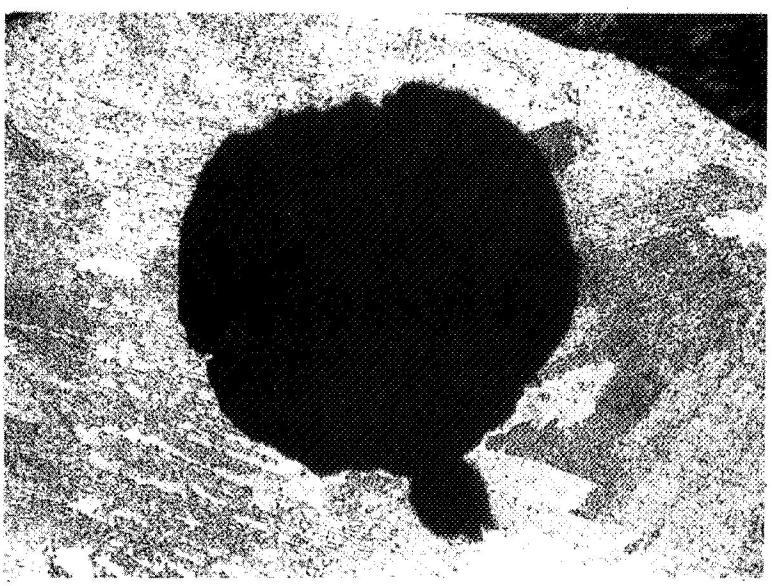
Figure 24b.

PHOTOMACROGRAPHS

TRANSVERSE SECTION



15 X MAG.
TAILED POROSITY

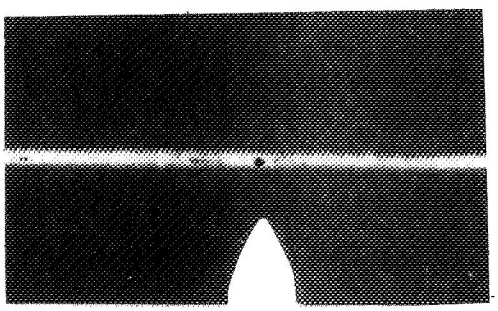


50 X MAG.

Figure 25a.

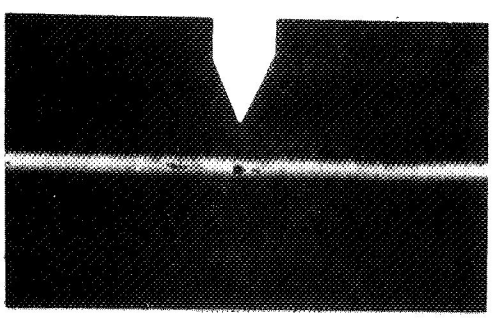
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2014
THICK. 0.063"

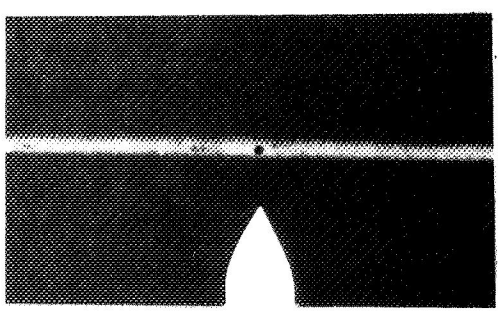


TAILED
POROSITY

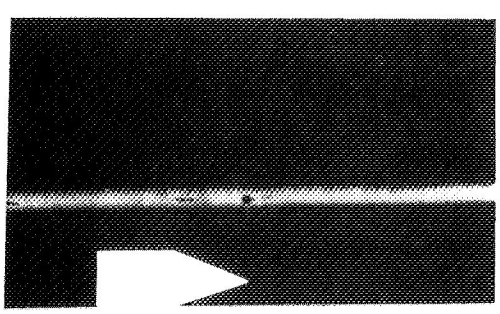
90°



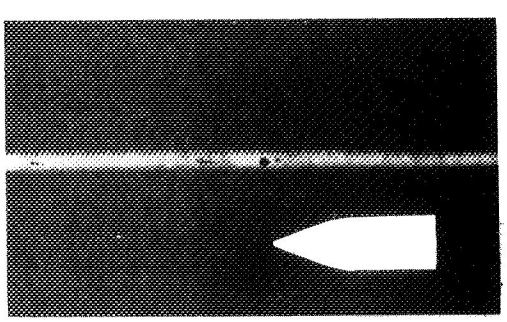
20°TL



20°TR



20°LL

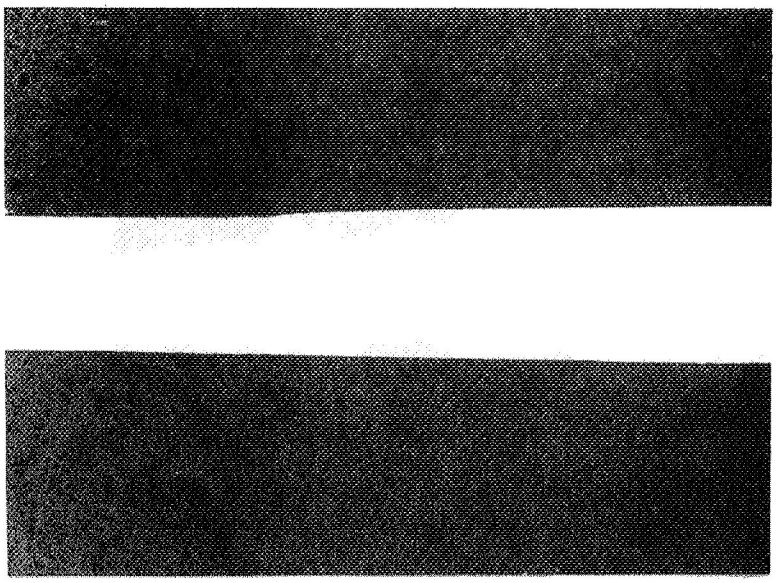


20°LR

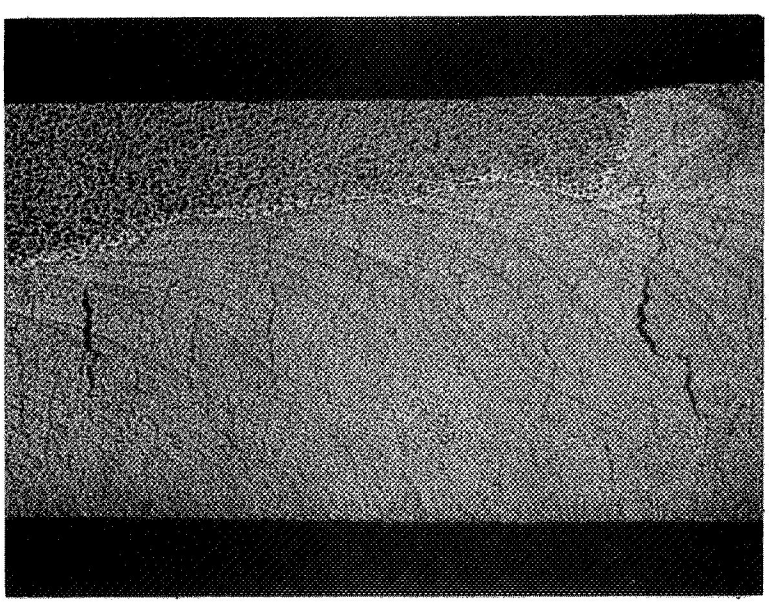
Figure 25b.

PHOTOMACROGRAPHS

PARALLEL SECTION



5 X MAG.
TRANSVERSE CRACKS

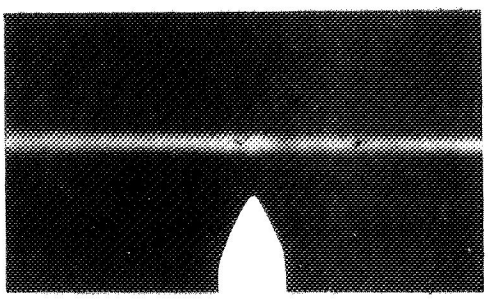


15 X MAG.

Figure 26a.

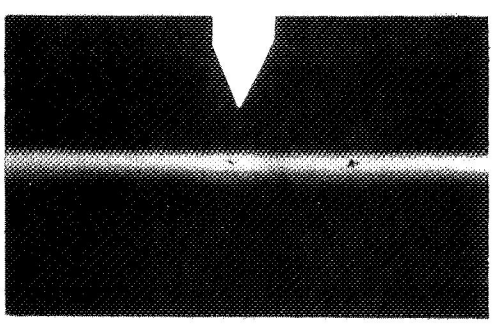
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2014
THICK. 0.063

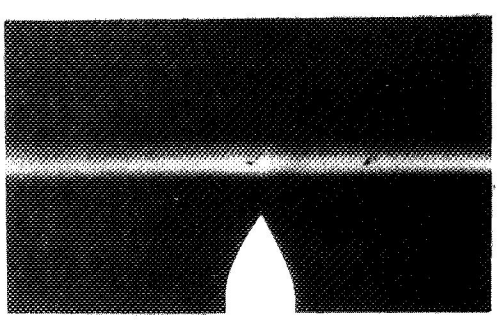


CRACK, TRANSVERSE

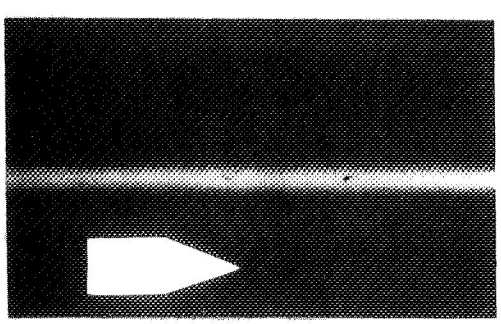
90°



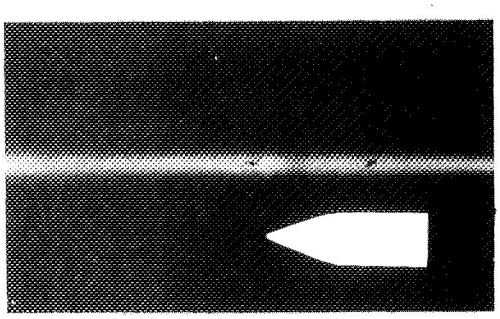
20°TL



20°TR



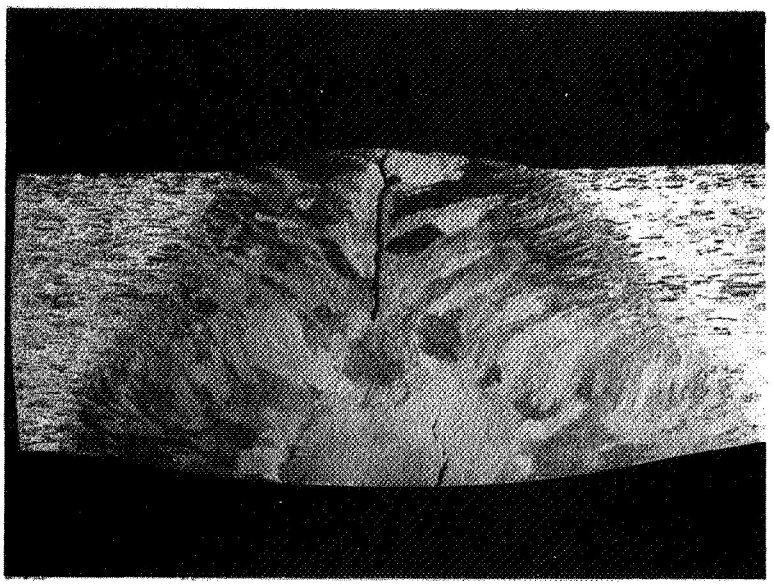
20°LL



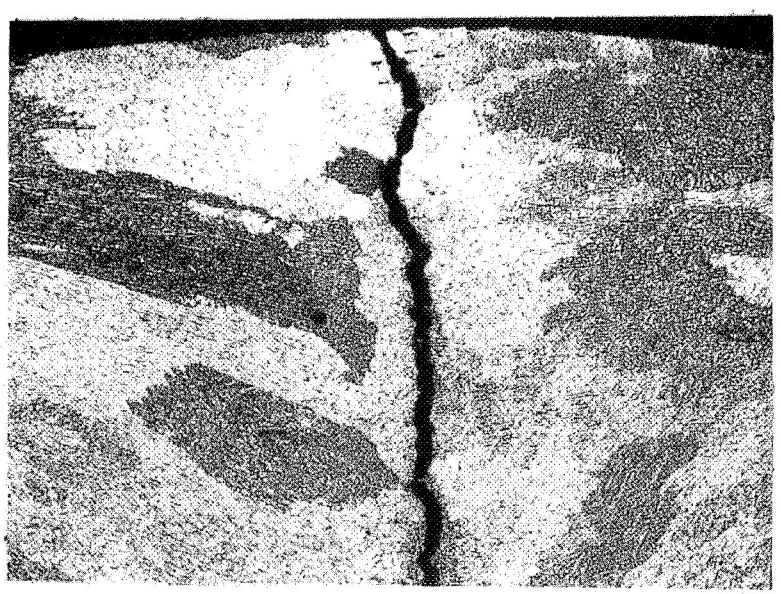
20°LR

Figure 26b.

PHOTOMACROGRAPHS
TRANSVERSE SECTION



10 X MAG.
LONGITUDINAL CRACK

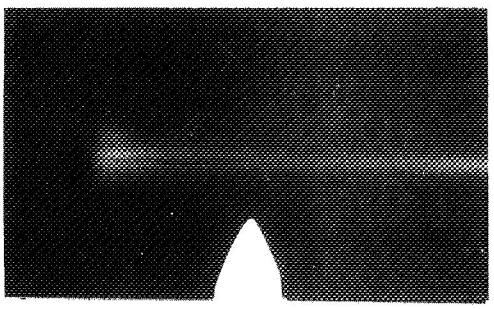


50 X MAG.

Figure 27a.

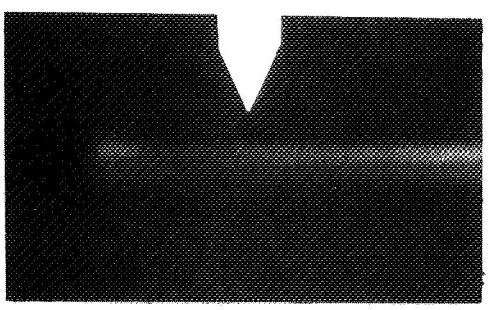
RADIOGRAPHS
OF
ALUMINUM WELDS

MAT. 2219
THICK. 0.125"

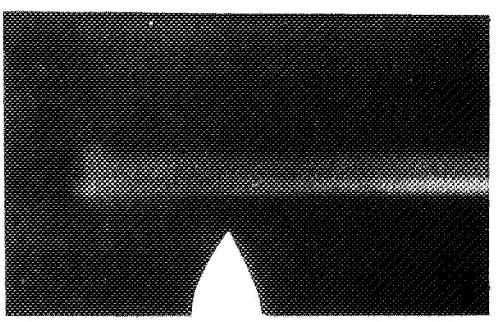


CRACK, LONGITUDINAL

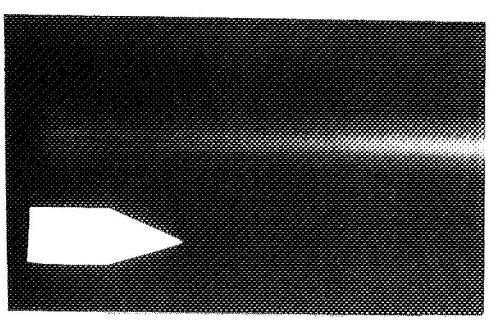
90°



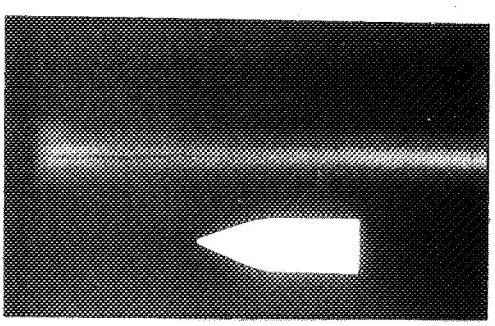
20°TL



20°TR



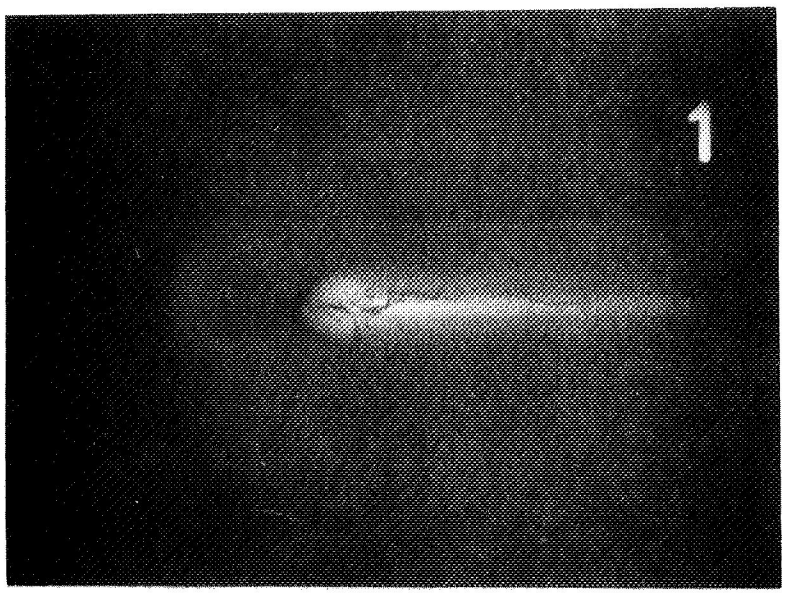
20°LL



20°LR

Figure 27b.

RADIOGRAPH OF AN ALUMINUM WELD



MAT. 2219 THICK. 0.392" CRATER CRACK

Figure 28a.

PHOTOMACROGRAPH
PLANED SECTION

5 X MAG. CRATER CRACK

Figure 28b.

APPROVAL

TM X-53939

RADIOGRAPHIC INTERPRETATION GUIDE FOR ALUMINUM ALLOY WELDS

By P. C. Duren and E. R. Risch

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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Chief, Materials Division

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